Package 'squarebrackets'

June 6, 2025

Type Package

Title Subset Methods as Alternatives to the Square Brackets Operators for Programming

Version 0.0.0.9000

Description Provides subset methods
(supporting both atomic and recursive S3 classes)
that may be more convenient alternatives to the `[` and `[<-` operators,
whilst maintaining similar performance.
Some nice properties of these methods include, but are not limited to, the following.
1) The `[` and `[<-` operators use different rule-sets for different data.frame-like types
(data.frames, data.tables, tibbles, tidytables, etc.).
The 'squarebrackets' methods use the same rule-sets for the different data.frame-like types.
2) Performing dimensional subset operations on an array using `[` and `[<-`,
requires a-priori knowledge on the number of dimensions the array has.
The 'squarebrackets' methods work on any arbitrary dimensions without requiring such prior knowledge.
3) When selecting names with the `[` and `[<-` operators,
only the first occurrence of the names are selected in case of duplicate names.
The 'squarebrackets' methods always perform on all names in case of duplicates,
not just the first.
4) The `[<-` operator only supports copy-on-modify semantics for most classes.
The 'squarebrackets' methods provides explicit pass-by-reference and pass-by-value semantics,
whilst still respecting things like binding-locks and mutability rules.
5) 'squarebrackets' supports index-less sub-set operations,
which is more memory efficient
(and better for the environment)
for `long vectors` than sub-set operations using the `[` and `[<-` operators.

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Encoding UTF-8

LinkingTo Rcpp

Roxygen list(markdown = TRUE)

RoxygenNote 7.3.2

Suggests rlang,
knitr,
rmarkdown,
tinytest,
tinycodet,
tidytable,

tibble,
ggplot2,
sf,
future.apply,
collections,
rrapply,
abind

Depends R (>= 4.2.0)

Imports Rcpp (>= 1.0.11),
collapse (>= 2.0.2),
data.table (>= 1.14.8),
stringi (>= 1.7.12)

URL https://github.com/tony-aw/squarebrackets/, https://tony-aw.github.io/squarebrackets/

BugReports https://github.com/tony-aw/squarebrackets/issues/

Language en-gb

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squarebrackets: Subset Methods as Alternatives to the Square Brackets Operators for Programming

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Description

squarebrackets:
Subset Methods as Alternatives to the Square Brackets Operators for Programming.

'squarebrackets' provides subset methods (supporting both atomic and recursive S3 classes) that may be more convenient alternatives to the `[` and `[<-` operators, whilst maintaining similar performance.
Some nice properties of these methods include, but are not limited to, the following.

1. The `[` and `[<-` operators use different rule-sets for different data.frame-like types (data.frames, data.tables, tibbles, tidytables, etc.).
   The 'squarebrackets' methods use the same rule-sets for the different data.frame-like types.
2. Performing dimensional subset operations on an array using `[` and `[<-`, requires a-priori knowledge on the number of dimensions the array has.
   The 'squarebrackets' methods work on any arbitrary dimensions without requiring such prior knowledge.
3. When selecting names with the `[` and `[<-` operators, only the first occurrence of the names are selected in case of duplicate names.
   The 'squarebrackets' methods always perform on all names in case of duplicates, not just the first.
4. The `[<-` operator only supports copy-on-modify semantics for most classes.
   The 'squarebrackets' methods provides explicit pass-by-reference and pass-by-value semantics, whilst still respecting things like binding-locks and mutability rules.
5. 'squarebrackets' supports index-less sub-set operations, which is more memory efficient (and better for the environment) for `long vectors` than sub-set operations using the `[` and `[<-` operators.

Goal

Among programming languages, 'R' has perhaps one of the most flexible and comprehensive sub-setting functionality, provided by the square brackets operators (`[`, `[<-`).
But in some situations the square brackets operators are occasionally less than optimally convenient

The Goal of the 'squarebrackets' package is not to replace the square-brackets operators, but to provide **alternative** sub-setting methods and functions, to be used in situations where the square bracket operators are inconvenient.

Overview Help Pages

Essentials

The essential documentation is split into the following help pages:

- squarebrackets_supported_structures:
  Lists the structures that are supported by 'squarebrackets', and explains some related terminology.
- squarebrackets_methods:
  Lists the main methods provided by 'squarebrackets'.
- squarebrackets_indx_fundamentals:
  Explains the essential fundamentals of the indexing forms in 'squarebrackets'.

Arguments

The methods in 'squarebrackets' share a lot of common arguments.
The explanations for these common arguments are given in the following help pages:

- squarebrackets_indx_args:
  Explains the common indexing arguments used in the main S3 methods.
- squarebrackets_modify:
  Explains the modification-related arguments, and other essential information regarding modification.
- squarebrackets_options:
  Lists and explains the options the user can specify in 'squarebrackets'.
- squarebrackets_slicev:
  Explains the special argument structure used in the `slicev_` methods.

Pass-By-Reference

The following help pages explain the pass-by-reference semantics provided by 'squarebrackets', and only need to be read when planning to use those semantics:

- squarebrackets_PassByReference:
  Explains Pass-by-Reference semantics, and its important consequences.
- squarebrackets_coercion:
  Explains the difference in coercion rules between modification through Pass-by-Reference semantics and modification through copy (i.e. pass-by-value).

Other

And finally, there is the squarebrackets_method_dispatch help page, which gives some small additional details regarding the S3 method dispatch used in 'squarebrackets'.

Helper Functions

A couple of convenience functions, and helper functions for creating ranges, sequences, and indices (often needed in sub-setting) are provided:

- n: Nested version of c, and short-hand for list.
- ndim: Get the number of dimensions of an object.
- sub2coord, coord2ind: Convert subscripts (array indices) to coordinates, coordinates to flat indices, and vice-versa.
- match_all: Find all matches, of one vector in another, taking into account the order and any duplicate values of both vectors.
- Computing indices:
  idx_r to compute an integer index range.
  idx_by to compute grouped indices.
  idx_ord_-functions to compute ordered indices.

Properties Details

The alternative sub-setting methods and functions provided by 'squarebrackets' have the following properties:

- **Programmatically friendly**:
  - Unlike base `[`, it's not required to know the number of dimensions of an array a-priori, to perform subset-operations on an array.
  - Missing arguments can be filled with `NULL`, instead of using dark magic like `base::quote(expr = )`.
  - No Non-standard evaluation.
  - Functions are pipe-friendly.
  - No (silent) vector recycling.
  - Extracting and removing subsets uses the same syntax.
- **Class consistent**:
  - sub-setting of multi-dimensional objects by specifying dimensions (i.e. rows, columns, ...) use `drop = FALSE`.
    So matrix in, matrix out.
  - The methods deliver the same results for data.frames, data.tables, tibbles, and tidytables.
    No longer does one have to re-learn the different brackets-based sub-setting rules for different types of data.frame-like objects.
    Powered by the subclass agnostic 'C'-code from 'collapse' and 'data.table'.
- **Explicit copy semantics**:
  - Sub-set operations that change its memory allocations, always return a modified (partial) copy of the object.
  - For sub-set operations that just change values in-place (similar to the `[<-` and `[[<-` methods) the user can choose a method that modifies the object by **reference**, or choose a method that returns a **(partial) copy**.
- **Careful handling of names**:
  - Sub-setting an object by index names returns ALL matches with the given names, not just the first.
  - Data.frame-like objects (see supported classes below) are forced to have unique column names.
  - Sub-setting arrays using `x[indx1, indx2, etc.]` will drop `names(x)`.
    The methods from 'squarebrackets' will not drop `names(x)`.

- **Concise function and argument names**.
- **Performance & Energy aware**:
  Despite the many checks performed, the functions are kept reasonably speedy, through the use of the 'Rcpp', 'collapse', and 'data.table' R-packages.
  The functions were also made to be as memory efficient as reasonably possible, to lower the carbon footprint of this package.

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References

The badges shown in the documentation of this R-package were made using the services of: https://shields.io/

`aaa01_squarebrackets_supported_structures`
Supported Structures

Description

'squarebrackets' only supports the most common S3 objects, and only those that primarily use square brackets for sub-set operations (hence the name of the package).

One can generally divide the structures supported by 'squarebrackets' along 3 key properties:

- atomic vs recursive:
  Types `logical`, `integer`, `double`, `complex`, `character`, and `raw` are `atomic`.
  Lists and data.frames are `recursive`.
- dimensionality:
  Whether an object is a vector, array, or data.frame.
  Note that a matrix is simply an array with 2 dimensions.
- mutability:
  Base R's S3 classes (except Environments) are generally immutable:
  Modifying the object will create a copy (called 'copy-on-modify').
  'squarebrackets also supports `data.tables` and mutatomic objects, which are mutable:
  If desired, one can modify them without copy using pass-by-reference semantics.

Supported Structures

'squarebrackets' supports the following immutable structures:

- basic `atomic` classes
  (atomic vectors and arrays).
- factor.

- basic list classes
  (recursive vectors and arrays).

- data.frame
  (including the classes `tibble`, `sf-data.frame` and `sf-tibble`).

'squarebrackets' supports the following mutable structures:

- mutatomic
  (`mutatomic` vectors arrays);
- data.table
  (including the classes `tidytable`, `sf-data.table`, and `sf-tidytable`).

The methods provided by 'squarebrackets', like any method, can be extended (by other 'R' package authors) to support additional classes that are not already supported natively by 'squarebrackets'.

Details

Atomic vs Recursive

The `i_/ss_` methods provided by 'squarebrackets' work on **atomic** (see is.atomic) objects.
The `i2_/ss2_` methods provided by 'squarebrackets' work on **recursive** (see is.recursive) objects.
See squarebrackets_methods for more details.

Dimensionality

'squarebrackets' supports dimensionless or vector objects (i.e. ndim `== 0L`).
squarebrackets' supports arrays (see is.array and is.matrix); note that a matrix is simply an array with 2 dimensions.
'squarebrackets' also supports data.frame-like objects (see is.data.frame).
Specifically, squarebrackets' supports a wide variety of data.frame classes:
`data.frame`, `data.table`, `tibble`, `tidytable`;
'squarebrackets' also supports their 'sf'-package compatible counter-parts:
`sf-data.frame`, `sf-data.table`, `sf-tibble`, `sf-tidytable`.

Dimensionless vectors and dimensional arrays are supported in both their atomic and recursive forms.
Data.frame-like objects, in contrast, only exist in the recursive form (and, as stated, are supported by 'squarebrackets').
Recursive vectors, recursive matrices, and recursive arrays, are collectively referred to as "lists" in the 'squarebrackets' documentation.

Note that the dimensionality of data.frame-like objects is not the same as the dimensionality of (recursive) arrays/matrices.
For example:
For any array/matrix `x`, it holds that `length(x) == prod(dim(x))`.
But for any data.frame `x`, it is the case that `length(x) == ncol(x)`.

Mutable vs Immutable
Most of base R's S3 classes (except Environments) are generally immutable:
Modifying the object will create a copy (called 'copy-on-modify').
They have no explicit pass-by-reference semantics.
Most S3 objects in base 'R' are immutable:
Environments do have pass-by-reference semantics, but they are not supported by 'squarebrackets'.

Supported mutable structures:

- 'squarebrackets' supports the mutable `data.table` class
  (and thus also `tidytable`, which inherits from `data.table`).
- 'squarebrackets' supports the mutatomic class.
  `mutatomic` objects are the same as atomic objects, except they are mutable (hence the name).

Supported immutable structures:
Atomic and recursive vectors/matrices/arrays, data.frames, and tibbles.

All the functions in the 'squarebrackets' package with the word "set" in their name perform pass-by-reference modification, and thus only work on mutable structures.
All other functions work the same way for both mutable and immutable structures.

Derived Atomic Vector
A special class of objects are the Derived Atomic Vector structures:
structures that are derived from atomic objects, but behave differently.
For example:
Factors, datetime, POSIXct and so on are derived from atomic vectors.
But they have attributes and special methods that make them behave differently.

'squarebrackets' treats derived atomic classes as regular atomic vectors.
There are highly specialized packages to handle objects derived from atomic objects.
For example, the 'anytime' package to handle date-time objects.

'squarebrackets does provide some more explicit support for factors.

Not Supported S3 structures
Key-Values storage S3 structures, such as environments, are not supported by 'squarebrackets'.

`aaa02_squarebrackets_methods`
Methods

Description

The main methods of 'squarebrackets' use the naming convention `A_B`:
`A` tells you on what kind of object and what kind of indices the method operates on;
`B` tells you **what operation** is performed.

For the `A` part, the following is available:

- `i_`: operates on subsets of **atomic** objects by (flat/linear) indices.
- `i2_`: operates on subsets of **recursive** objects by (flat/linear) indices.
- `ss_`: operates on subsets of **atomic** objects by (dimensional) subscripts.
- `ss2_`: operates on subsets of **recursive** objects by (dimensional) subscripts.
- `slice_`: uses **index-less**, **sequence-based**, and efficient operations on `mutatomic` objects.
- `slicev_`: uses **index-less**, **value-based** and efficient operations on `mutatomic` objects.

For the `B` part, the following is available:

- `_x`: extract, exchange, or duplicate (if applicable) subsets.
- `_wo`: returns the original object **without** the provided subsets.
- `_mod`: modify subsets and return copy.
- `_set`: modify subsets using pass-by-reference semantics.
- `_rec`: access recursive subsets of lists - ONLY available with the `i2_` prefix.
- `_recin`: replace, transform, delete, or extend recursive subsets of lists - ONLY available with the `i2_` prefix.

There is also the somewhat separate idx method, which works on both recursive and non-recursive objects.

Thus, for example, the i_x method extracts/exchanges/duplicates subsets of atomic objects by flat/linear indices.

Illustration

To illustrate, let's take the methods used for extracting subsets (`_x`):
When `y` is atomic, the following holds (roughly speaking):

- `i_x(y, i)` corresponds to `y[i]`
- `ss_x(y, n(i, k), c(1, 3))` corresponds to `y[i, , k]`

When `y` is a list (i.e. recursive), the following holds (roughly speaking):

- `i2_x(y, i)` corresponds to `y[i]` or `y[[i]]` (depending on the arguments given in `i2_x()`)
- `ss2_x(y, n(i, k), c(1, 3))` corresponds to `y[i, , k]` or `y[[i, , k]]` (depending on the arguments given in `ss2_x()`)

Finding the Appropriate Help Pages

Now that it is clear what the naming convention is of the main methods, one can easily find out information about a particular method by usign the ? operator.
So to find out about modifying recursive objects by reference using dimensional indices, type in:
`?ss2_set`

Note that some combinations of `A` and `B` are not available.
For example, as the `_rec` `_recin` suffices are only applicable for recursive objects using linear indices, only `i2_rec` and `i2_recin` exist;
combinations like `i_rec`, `ss_recin`, etc. don't exist.
Another example: there is no `_mod` suffix available for the `slice_` and `slicev_` methods.

`aaa03_squarebrackets_indx_fundamentals`
Indexing Fundamentals

Description

This help page explains the fundamentals regarding how 'squarebrackets' treats indexing.
Some familiarity with base R's `[` and `[<-` operators is required to follow this help page.

Indexing Types

Base 'R' supports indexing through `logical`, `integer`, and `character` vectors.
'squarebrackets' supports these also (albeit with some improvements), but also supports some additional methods of indexing.

Whole numbers

Whole numbers are the most basic form on index selection.
All forms of indexing in 'squarebrackets' are internally translated to integer (or double if `> (2^31 - 1)`) indexing first, ensuring consistency.
Indexing through integer/numeric indices in 'squarebrackets' works the same as in base 'R', except that negative values are not allowed.
So indexing starts at `1` and is inclusive.

Logical

Selecting indices with a logical vector in 'squarebrackets' works the same as in base 'R', except that recycling is not allowed.

Characters

When selecting indices using a character vector, base 'R' only selects the first matches in the names.
'squarebrackets', however, selects all matches:

```
nms <- c("a", letters[4:1], letters[1:5])
x <- 1:10
names(x) <- nms
print(x) #' `x` has multiple elements with the name "a"
#>  a  d  c  b  a  a  b  c  d  e
#>  1  2  3  4  5  6  7  8  9 10

i_x(x, "a") # extracts all indices with the name "a"
#> a a a
#> 1 5 6

i_x(x, c("a", "a")) # repeats all indices with the name "a"
#> a a a a a a
#> 1 5 6 1 5 6
```

Character indices are internally translated to integer indices using match_all.

Imaginary Numbers
A complex vector y is structured as
y = a + b * i
where Re(y) returns a, and Im(y) returns b.
squarebrackets' includes support for indexing through imaginary numbers (Im(y)) of complex vectors.
Indexing with imaginary numbers is a generalization of indexing with regular integers.

It works as follows:
Imaginary numbers that are positive integers, like 1:10 * 1i, work the same as regular integers.
Imaginary numbers that are negative integers, like 1:10 * -1i, index by counting backwards (i.e. from the end).
Note that **only** the Imaginary part of a complex vector is used (Im(y));
the Real part (Re(y)) is **ignored**.

See the results of the following code as an example:

```
x <- 1:30 # vector of 30 elements

i_x(x, 1:10 * 1i) # extract first 10 elements
#>  [1]  1  2  3  4  5  6  7  8  9 10

i_x(x, 1:10 * -1i) # extract last 10 elements
#>  [1] 30 29 28 27 26 25 24 23 22 21

i_x(x, 10:1 * -1i) # last 10 elements, in tail()-like order
#>  [1] 21 22 23 24 25 26 27 28 29 30
```

Thus complex vectors allow the user to choose between counting from the beginning, like regular integers, or backwards counting from the end.

Flat Indices and Subscripts

One can operate on flat/linear indices (often simply referred to as "indices") using the `i_`/ `i2_` methods;
These primarily use the i argument.

One can operate on subscripts (= dimensional indices) using the `ss_`/ `ss2_` methods;
These primarily use the the s, d argument pair.
(Given, for example, a 3-dimensional array, the subscript `[1:10, 2:5, 3:9]`, refers to rows 1 to 10, columns 2 to 5, and layers 3 to 9.)

The s, d argument pair works consistently for any dimensional object supported by 'squarebrackets', and does not require a-priori knowledge on the number of dimensions the object has.
This is particularly useful for arrays, which can have any number of dimensions.

Arrays and matrices (matrices are simply arrays with 2 dimensions) support both flat indices (using the `i_`/ `i2_` methods) and subscripts (using the `ss_`/ `ss2_` methods).
In the flat indices, also called linear indices, specify the indices of an array as-if it is vector, thus ignoring dimensions.

For the relationship between flat indices and subscripts for arrays, see the sub2ind help page.

Inverting

Inverting indices means to specify all elements **except** the given indices.
Consider for example the atomic vector `month.abb` (abbreviate month names).
Given this vector, indices `1:5` gives `c("Jan" "Feb" "Mar" "Apr", "May")`.
Inverting those same indices will give `c("Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec")`.

In base 'R', inverting an index is done in different ways.
(negative numbers for numeric indexing, negation for logical indexing, manually un-matching for character vectors).

'squarebrackets' provides a (somewhat) consistent syntax to invert indices:

- The methods that end with `_x` perform extraction;
  to invert extraction, i.e. return the object **without** the specified subset, use the methods that end with `_wo`.

- In the modification methods (`_mod_`/`_set_`) one can set the argument inv = `TRUE` to invert indices.

EXAMPLES

```
x <- month.abb
print(x)
#>  [1] "Jan" "Feb" "Mar" "Apr" "May" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"
```

```
i_x(x, 1:5) # extract first 5 elements
#> [1] "Jan" "Feb" "Mar" "Apr" "May"

i_wo(x, 1:5) # return WITHOUT first 5 elements
#> [1] "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"


i_mod(x, 1:5, rp = "XXX") # copy, replace first 5 elements, return result
#>  [1] "XXX" "XXX" "XXX" "XXX" "XXX" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"

i_mod(x, 1:5, inv = T, rp = "XXX") # same, but for all except first 5 elements
#>  [1] "Jan" "Feb" "Mar" "Apr" "May" "XXX" "XXX" "XXX" "XXX" "XXX" "XXX" "XXX"
```

ABOUT ORDERING
The order in which the user gives indices when inverting indices generally does not matter.
The order of the indices as they appear in the original object `x` is maintained, just like in base 'R'.

Out-of-Bounds Integers, Non-Existing Names, and NAs

- Integer indices that are out of bounds (including `NaN` and `NA_integer_`) always give an error.
- Character indices that specify non-existing names is considered a form of zero-length indexing.
  Specifying `NA` names returns an error.

- Logical indices are translated internally to integers using which, and so `NA`s are ignored.

Index-less Sub-set Operations

Until now this help page focussed on performing sub-set operations with an indexing vector.

Performing sub-set operations on a long vector using a index vector (which may itself also be a long vector) is not very memory-efficient.
'squarebrackets' therefore introduces index-less sub-set operations, through the slice_ and slicev_ methods.
These methods are much more memory and computationally efficient than index-based sub-set methods (and so also a bit better for the environment!).

The slice_ methods perform sequence based sub-set operations.

The slicev_ methods (notice the "v" at the end) perform value-based sub-set operations.
Though this method is intentionally kept relatively simple, it is still involved enough to warrant its own help page;
for the details on value-based index-less sub-set operations, please see squarebrackets_slicev.

Regarding Performance

Integer vectors created through the `:` operator are "compact ALTREP" integer vectors, and provide the fastest way to specify indices.
Indexing through names (i.e. character vectors) is the slowest.
Complex vectors of imaginary numbers are somewhat in the middle in terms of speed.

Index-less sub-set operations are usually faster and more memory efficient than any index-based sub-set operation.
So if performance is important, use index-less sub-set operations, or use compact ALTREP integer indices.

Indexing in Recursive Subsets

Until now this help page focussed on indexing for regular (or "shallow") subsets.
This section will discuss indexing in recursive subsets.

One of the differences between atomic and recursive objects, is that recursive objects support recursive subsets, while atomic objects do not.

Bear in mind that every element in a recursive object is a reference to another object.
Consider the following list `x`:

```
x <- list(
   A = 1:10,
   B = letters,
   C = list(A = 11:20, B = month.abb)
)
```

Regular subsets, AKA surface-level subset operations (`[`, `[<-` in base 'R'), operate on the recursive object itself.
I.e. i2_x`(x, 1)`, or equivalently `x[1]`, returns the **list** `list(A = 1:10)`:

```
i2_x(x, 1) # equivalent to x[1]; returns list(A = 1:10)
#> $A
#>  [1]  1  2  3  4  5  6  7  8  9 10
```

Recursive subset operations (`[[`, `[[<-`, and `$` in base 'R'), on the other hand, operate on an object a subset of the recursive object references to.
I.e. i2_rec`(x, 1)`, or equivalently `x[[1]]`, returns the **integer vector** `1:10`:

```
i2_rec(x, 1) # equivalent to x[[1]]; returns 1:10
#>  [1]  1  2  3  4  5  6  7  8  9 10
```

Recursive objects can refer to other recursive objects, which can themselves refer to recursive objects, and so on.
Recursive subsets can go however deep you want.
So, for example, to extract the character vector `month.abb` from the aforementioned list `x`, one would need to do:
i2_rec`(x, c("C","B"))`, (in base R: `x$C$B`):

```
i2_rec(x, c("C","B")) # equivalent to x$C$B
#>  [1] "Jan" "Feb" "Mar" "Apr" "May" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"

# or:

i2_rec(x, c(3, 2)) # equivalent to x[[3]][[2]]
#>  [1] "Jan" "Feb" "Mar" "Apr" "May" "Jun" "Jul" "Aug" "Sep" "Oct" "Nov" "Dec"
```

LIMITATIONS
Indexing in recursive subsets is significantly more limited than in regular (or "shallow") subsets:

- Recursive subset operations using i2_rec/i2_recin only support positive integer vectors and character vectors.
- Imaginary numbers (using complex vectors) and logical vectors are not supported.
- Since a recursive subset operation only operates on a single element, specifying the index with a character vector only selects the first matching element (just like base 'R'), not all matches.
- Inverting indices is also **not** available for recursive indexing.
- Unlike regular sub-setting, out-of-bounds specification for indices is acceptable, as it can be used to add new values to lists.

Non-Standard Evaluation

'squarebrackets' is designed primarily for programming, and seeks to be fully programmatically friendly.
As part of this endeavour, 'squarebrackets' never uses Non-Standard Evaluation.
All input for all methods and functions in 'squarebrackets' are objects that can be stored in a variable.
Like atomic vectors, lists, formulas, etc.

`aaa04_squarebrackets_indx_args`
Index Arguments in the Generic Sub-setting Methods

Description

There are several types of arguments that can be used in the generic methods of 'squarebrackets' to specify the indices to perform operations on:

- `i`: to specify flat (i.e. dimensionless) indices.
- `s, d`: to specify indices of arbitrary dimensions in any dimensional object supported by 'squarebrackets' (i.e. arrays and data.frame-like objects).
- `margin, slice`: to specify indices of one particular dimension (for arrays and data.frame-like objects).
  Only used in the idx method.
- `obs, vars`: to specify observations and/or variables in specifically in data.frame-like objects.

For the fundamentals of indexing in 'squarebrackets', see squarebrackets_indx_fundamentals.
In this help page `x` refers to the object on which subset operations are performed.

Argument i

class: atomic vector
class: derived atomic vector
class: recursive vector
class: atomic array
class: recursive array

Any of the following can be specified for argument `i`:

- `NULL`, corresponds to missing argument.
- a vector of length 0, in which case no indices are selected for the operation (i.e. empty selection).
- a numeric vector of **strictly positive whole numbers** giving indices.
- a **complex** vector, as explained in squarebrackets_indx_fundamentals.
- a **logical vector**, of the same length as `x`, giving the indices to select for the operation.
- a **character** vector of index names.
  If an object has multiple indices with the given name, ALL the corresponding indices will be selected for the operation.
- a **function** that takes as input `x`, and returns a logical vector, giving the element indices to select for the operation.
  For atomic objects, `i` is interpreted as `i(x)`.
  For recursive objects, `i` is interpreted as `lapply(x, i)`.

Using the `i` arguments corresponds to doing something like the following:

```
i_x(x, i = i) # ==> x[i]   # if `x` is atomic
i2_x(x, i = i) # ==> x[i]  # if `x` is recursive
```

If `i` is a function, it corresponds to the following:

```
i_x(x, i = i) # ==> x[i(x)] # if `x` is atomic
i2_x(x, i = i) # ==> x[lapply(x, i)] # if `x` is recursive
```

Argument Pair s, d

class: atomic array
class: recursive array
class: data.frame-like
The `s, d` argument pair, inspired by the `abind::asub` function from the 'abind' package, is the primary indexing argument for sub-set operations on dimensional objects.

The `s` argument specifies the **subscripts** (i.e. dimensional indices).
The `d` argument gives the dimensions for which the `s` holds (i.e. `d` specifies the "non-missing" margins).

The `d` argument must be an integer vector.

`s` must be an atomic vector, a list of length 1, or a list of the same length as `d`.
If `s` is a list of length 1, it is internally recycled to become the same length as `d`.
If `s` is an atomic vector, it is internally treated as `list(s)`, and (as with the previous case) recycled to become the same length as `d`.

Each element of `s` when `s` is a list, or `s` as a whole when `s` is atomic, can be any of the following:

- a vector of length 0, in which case no indices are selected for the operation (i.e. empty selection).
- a numeric vector of **strictly positive whole numbers** with indices of the specified dimension to select for the operation.
- a **complex** vector, as explained in squarebrackets_indx_fundamentals.
- a **logical** vector of the same length as the corresponding dimension size, giving the indices of the specified dimension to select for the operation.
- a **character** vector giving the `dimnames` to select.
  If a dimension has multiple indices with the given name, ALL the corresponding indices will be selected for the operation.

Note the following:

- As stated, `d` specifies which index margins are non-missing.
  If `d` is of length `0`, it is taken as "all index margins are missing".
- The default value for `d` is `1:ndim(x)`.

To keep the syntax short, the user can use the n function instead of `list()` to specify `s`.

EXAMPLES
Here are some examples for clarity, using an atomic array `x` of 3 dimensions:

- `ss_x(x, n(1:10, 1:5), c(1, 3))`
  extracts the first 10 rows, all columns, and the first 5 layers, of array `x`.

- `ss_x(x, n(1:10), 2)`
  extracts the first 10 columns of array `x`.

- `ss_x(x, 1:10),`
  extracts the first 10 rows, columns, and layers of array `x`.

- `ss_x(x, 1:10, c(1, 3)),`
  extracts the first 10 rows, all columns, and the first 10 layers, of array `x`.

I.e.:

```
ss_x(x, n(1:10, 1:5), c(1, 3)) # ==> x[1:10, , 1:5, drop = FALSE]

ss_x(x, 1:10, 2)               # ==> x[ , 1:10, , drop = FALSE]

ss_x(x, 1:10)                  # ==> x[1:10, 1:10, 1:10, drop = FALSE]

ss_x(x, 1:10, c(1, 3))         # ==> x[1:10, , 1:10, drop = FALSE]
```

For a brief explanation of the relationship between flat indices (`i`) and subscripts (`s`, `d`) in arrays, see sub2ind.

Argument Pair margin, slice

class: atomic array
class: recursive array
class: data.frame-like

Relevant only for the idx method.
The `margin` argument specifies the dimension on which argument `slice` is used.
I.e. when `margin = 1`, `slice` selects rows;
when `margin = 2`, `slice` selects columns;
etc.

The `slice` argument can be any of the following:

- a numeric vector of **strictly positive whole numbers** with dimension indices to select for the operation.
- a **complex** vector, as explained in squarebrackets_indx_fundamentals.
- a **logical** vector of the same length as the corresponding dimension size, giving the dimension indices to select for the operation.
- a **character** vector of index names.
  If a dimension has multiple indices with the given name, ALL the corresponding indices will be selected for the operation.

One could also give a vector of length `0` for `slice`;
Argument `slice` is only used in the idx method , and the result of idx are meant to be used inside the regular `[` and `[<-` operators.
Thus the effect of a zero-length index specification depends on the rule-set of `[.class(x)` and `[<-.class(x)`.

Arguments obs, vars

class: data.frame-like
The `obs` argument specifies indices for observations (i.e. rows) in data.frame-like objects.

The `vars` argument specifies indices for variables (i.e. columns) in data.frame-like objects.
The `obs` and `vars` arguments are inspired by the `subset` and `select` arguments, respectively, of base R's `subset.data.frame` method. However, the `obs` and `vars` arguments do **not** use non-standard evaluation, as to keep 'squarebrackets' fully programmatically friendly.

The `obs` Argument
The `obs` argument can be any of the following:

- `NULL` (default), corresponds to a missing argument.
- a vector of length 0, in which case no indices are selected for the operation (i.e. empty selection).
- a numeric vector of **strictly positive whole numbers** with row indices to select for the operation.
- a **complex** vector, as explained in squarebrackets_indx_fundamentals.
- a **logical** vector of the same length as the number of rows, giving the row indices to select for the operation.
- a **one-sided formula**, with a single logical expression using the column names of the data.frame, giving the condition which observation/row indices should be selected for the operation.

So to perform an operation on the observations for which holds that `height > 2` and `sex != "female"`, specify the following formula:

```
obs = ~ (height > 2) & (sex != "female")
```

If the formula is linked to an environment, any variables not found in the data set will be searched from the environment.

The `vars` Argument
The `vars` argument can be any of the following

- `NULL` (default), corresponds to a missing argument.
- a vector of length 0, in which case no indices are selected for the operation (i.e. empty selection).
- a numeric vector of **strictly positive whole numbers** with column indices to select for the operation.
- a **complex** vector, as explained in squarebrackets_indx_fundamentals.
- a **logical** vector of the same length as the number of columns, giving the column indices to select for the operation.
- a **character** vector giving the `colnamess` to select.
  Note that 'squarebrackets' assumes data.frame-like objects have unique column names.
- a **function** that returns a logical vector, giving the column indices to select for the operation.
  For example, to select all numeric variables, specify `vars = is.numeric`.
- a **two-sided formula**, where each side consists of a single term, giving a range of names to select.
  For example, to select all variables between and including the variables "height" and "weight", specify the following:
  `vars = heigth ~ weight`.

EXAMPLE

So using the `obs, vars` arguments corresponds to doing something like the following:

```
ss2_x(x, obs = obs, vars = vars) # ==> subset(x, ...obs..., ...vars...)
```

Argument inv

all classes

Relevant for the `_mod`,`_set`, and idx methods.
By default, `inv = FALSE`, which translates the indices like normally.
When `inv = TRUE`, the inverse of the indices is taken.
Consider, for example, an atomic matrix `x`;
using `i_mod(x, 1:2, 2L, tf = tf)` corresponds to something like the following:

```
x[, 1:2] <- tf(x[, 1:2])
x
```

and using `ss_mod(x, vars = 1:2, inv = TRUE, tf = tf)` corresponds to something like the following:

```
x[, -1:-2] <- tf(x[, -1:-2])
x
```

NOTE
The order in which the user gives indices when `inv = TRUE` generally does not matter.
The order of the indices as they appear in the original object `x` is maintained, just like in base 'R'.
Therefore, when replacing multiple values where the order of the replacement matters, it is better to keep `inv = FALSE`, which is the default.
For replacement with a single value or with a transformation function, `inv = TRUE` can be used without considering the ordering.

All Missing Indices

`NULL` in the indexing arguments corresponds to a missing argument.
For `s, d`, specifying `d` of length 0 also corresponds to all subscripts being missing.
Thus, for **both** the `_x` and `_wo` methods, using missing or `NULL` indexing arguments for all indexing arguments corresponds to something like the following:

```
x[]
```

Similarly, for the `_mod` and `_set` methods, using missing or `NULL` indexing arguments corresponds to something like the following:

```
x[] <- rp # for replacement
x[] <- tf(x) # for transformation
```

The above is true **even if** `inv = TRUE` and/or `red = TRUE`.

Disallowed Combinations of Index Arguments

One cannot specify the `s, d` pair and `obs, vars` pair simultaneously; it's either one pair or the other pair.
One cannot specify the `s, d` pair and `slice, margin` pair simultaneously; it's either one pair or the other pair.
In the above cases it holds that if one set is specified, the other is set is ignored.

Drop

Sub-setting with the generic methods from the 'squarebrackets' R-package using dimensional arguments (`s, d, row, col filter, vars`) always use `drop = FALSE`.
To drop potentially redundant (i.e. single level) dimensions, use the drop function, like so:

```
ss_x(x, s, d) |> drop() # ==> x[..., drop = TRUE]
```

References

Plate T, Heiberger R (2016). *abind: Combine Multidimensional Arrays*. R package version 1.4-5, https://CRAN.R-project.org/package=abind.

---

aaa05_squarebrackets_modify

Regarding Modification

Description

This help page describes the main modification semantics available in 'squarebrackets'.

Base R's default modification

For most average users, R's default copy-on-modify semantics are fine.
The benefits of the indexing arguments from 'squarebrackets' can be combined the `[<-` operator, through the idx method.
The result of the `idx()` method can be used inside the regular square-brackets operators.
For example like so:

```
x <- array(...)
my_indices <- idx(x, s, d)
x[my_indices] <- value

y <- data.frame(...)
rows <- idx(y, 1:10, 1, inv = TRUE)
cols <- idx(y, c("a", "b"), 2)
y[rows, cols] <- value
```

thus allowing the user to benefit from the convenient index translations from 'squarebrackets', whilst still using R's default copy-on-modification semantics (instead of the semantics provided by 'squarebrackets').

Explicit Copy

'squarebrackets' provides the `_mod` method to modify through a (shallow) copy.
This method returns the modified object.
For recursive objects, i2_mod/ss2_mod returns the original object, where only the modified subsets are copied, thus preventing unnecessary usage of memory.

Pass-by-Reference

'squarebrackets' provides the i_set, ss_set, ss2_set and slice_set methods to modify by reference, meaning no copy is made at all.
Pass-by-Reference is fastest and the most memory efficient.
But it is also more involved than the other modification forms, and requires more thought.
See squarebrackets_PassByReference for more information.

Replacement and Transformation in Atomic Objects

The `rp` argument is used to replace the values at the specified indices with the values specified in `rp`.
Using the `rp` argument in the modification methods, corresponds to something like the following:

```
x[...] <- rp
```

The `tf` argument is used to transform the values at the specified indices through transformation function `tf`. Using the `tf` argument corresponds to something like the following:

```
x[...] <- tf(x[...])
```

where `tf` is a function that **returns** an object of appropriate type and size (so `tf` should not be a pass-by-reference function).

Replacement and Transformation in Lists

The `rp` and `tf` arguments work mostly in the same way for recursive objects.
But there are some slight differences.

Argument `rp`
'squarebrackets' demands that `rp` is always provided as a list in the S3 methods for recursive vectors, matrices, and arrays (i.e. lists).
This is to prevent ambiguity with respect to how the replacement is recycled or distributed over the specified indices
(See `Footnote 1` below).

Argument `tf`
Most functions in (base) 'R' are vectorized for atomic objects, but not for lists
(see `Footnote 2` below).
'squarebrackets' will therefore apply transformation function `tf` via `lapply`, like so:

```
x[...] <- lapply(x[...], tf)
```

In the methods for recursive objects, the `tf` argument is accompanied by the `.lapply` argument.
By default, `.lapply = lapply`.
The user may supply a custom `lapply()`-like function in this argument to use instead.
For example, to perform parallel transformation, the user may supply `future.apply::future_lapply`.
The supplied function must use the exact same argument convention as lapply, otherwise errors or unexpected behaviour may occur.

Replacement and Transformation in data.frame-like Objects

Replacement and transformations in data.frame-like objects are a bit more flexible than in Lists.

`rp` is not always demanded to be a list for data.frame-like objects, only when appropriate (for example, when replacing multiple columns, or when the column itself is a list.)
Bear in mind that every column in a data.frame is like an element in a list;
so `.lapply` is used for transformations across multiple columns.

Recycling and Coercion

Recycling is not allowed in the modification methods.
So, for example, `length(rp)` must be equal to the length of the selected subset, or equal to `1`.

When using Pass-by-Reference semantics, the user should be extra mindful of the auto-coercion rules.
See squarebrackets_coercion for details.

Footnotes

Footnote 1
Consider the following replacement in base 'R':

```
x <-list(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
x[1:2] <- 2:1
```

What will happen?
Will the `x[1]` be `list(1:2)` and `x[2]` also be `list(1:2)`?
Or will `x[1]` be `list(2)` and `x[2]` be `list(1)`?
It turns out the latter will happen; but this is somewhat ambiguous from the code.
To prevent such ambiguity in your code, 'squarebrackets' demands that `rp` is always provided as a list.

Footnote 2
Most functions in (base) 'R' are vectorized for atomic objects, but not for lists.
One of the reasons is the following:
In an atomic vector `x` of some type `t`, every single element of `x` is a scalar of type `t`.
However, every element of some list `x` can be virtually anything:
an atomic object, another list, an unevaluated expression, even dark magic like `quote(expr =)`.
It is difficult to make a vectorized function for an object with so many unknowns.
Therefore, in the vast majority of the cases, one needs to loop through the list elements.

`aaa06_squarebrackets_options`
squarebrackets Options

Description

This help page explains the various global options that can be set for the 'squarebrackets' package, and how it affects the functionality.

Check Duplicates

argument: chkdup
option: squarebrackets.chkdup
The $*$`_x` methods are the only methods where providing duplicate indices actually make sense.
For the other methods, it doesn't make sense.
Giving duplicate indices usually won't break anything; however, when replacing/transforming or

removing subsets, it is almost certainly not the intention to provide duplicate indices.
Providing duplicate indices anyway might lead to unexpected results.
Therefore, for the methods where giving duplicate indices does not make sense, the chkdup argument is present.
This argument controls whether the method in question checks for duplicates (TRUE) or not (FALSE).

Setting chkdup = TRUE means the method in question will check for duplicate indices, and give an error when it finds them.

Setting chkdup = FALSE will disable these checks, which saves time and computation power, and is thus more efficient.

Since checking for duplicates can be expensive, it is set to FALSE by default.
The default can be changed in the squarebrackets.chkdup option.

Sticky

argument: sticky
option: squarebrackets.sticky
The slice_x, slice_wo, and slicev_x methods can already handle names (through the use.names argument), attributes specific to the mutatomic class, and attributes specific to the factor class.

Attributes which are not names, and not specific to mutatomic class, and not specific to the factor class - henceforth referred to as "other attributes" - are treated differently.
How the slice_x, slice_wo, and slicev_x methods handle these "other" attributes, is determined by the sticky option and argument.

When sticky = FALSE, the slice_x, slice_wo, and slicev_x methods will drop all **other** attributes.

By setting sticky = TRUE, all these **other** attributes, except comment and tsp, will be preserved;
The key advantage for this, is that classes that use static attributes (i.e. classes that use attributes that do not change when sub-setting), are automatically supported if sticky = TRUE, and no separate methods have to written for the slice_x, slice_wo, and slicev_x methods.
Attributes specific to classes like difftime, Date, POSIXct, roman, hexmode, octmode, and more, use static attributes.

Instead of setting sticky = TRUE or sticky = FALSE, one can also specify all classes that use static attributes that you'll be using in the current R session.
In fact, when 'squarebrackets' is **loaded**, the squarebrackets.sticky option is set as follows:

```
squarebrackets.sticky = c(
   "difftime", "Date", "POSIXct", "roman", "hexmode", "octmode"
)
```

So in the above default setting, sticky = TRUE for
"difftime", "Date", "POSIXct", "roman", "hexmode", "octmode".
Also in the above default setting, sticky = FALSE for other classes.

The reason the slice_x, slice_wo, and slicev_x methods need the sticky option, is because of

the following.
Unlike the `i_`, `i2_`, `ss_`, and `ss2_` methods, the slice_x, slice_wo, and slicev_x methods are not wrappers around the `[` and `[<-` operators.
Therefore, most `[` - S3 methods for highly specialized classes are not readily available for the slice_x, slice_wo, and slicev_x methods.
Which in turn means important class-specific attributes are not automatically preserved.
The `sticky` option is a convenient way to support a large number of classes, without having to write specific methods for them.

For specialized classes that use attributes that **do** change when sub-setting, separate dispatches for the slice_x, slice_wo, and slicev_x methods need to be written.
Package authors are welcome to create method dispatches for their own classes for these methods.

`aaa07_squarebrackets_method_dispatch`
Method Dispatch of 'squarebrackets'

Description

This help page gives some additional details regarding the S3 method dispatch used in 'squarebrackets'.

Atomic vs Recursive

Atomic and recursive objects are quite different from each other in some ways:

- **homo- or heterogeneous**: an atomic object can only have values of one data type.
  recursive objects can hold values of any combination of data types.

- **nesting**: Recursive objects can be nested, while atomic objects cannot be nested.
- **copy and coercion effect**: One can coerce or copy a subset of a recursive object, without copying the rest of the object.
  For atomic objects, however, a coercion or copy operation coerces or copies the entire vector (ignoring attributes).

- **vectorization**: most vectorized operations generally work on atomic objects, whereas recursive objects often require loops or apply-like functions.

- **recursive subsets**: Recursive objects distinguish between "regular" subset operations (in base R using `[`, `[<-`), and recursive subset operations (in base R using `[[`, `[[<-`).
  See for example the i2_rec method, or the `red = TRUE` argument in the `*_x` and `*_wo` methods.
  For atomic objects, these 2 have no meaningful difference (safe for perhaps some minor attribute handling).

- **views**: For recursive objects, one can create a View of a recursive subset (see the documentation in the 'mutatomic' package for details).
  Subset views do not exist for atomic objects.

Ellipsis

Due to how the S3 method dispatch system works in 'R', all generic methods have the ellipsis argument (...).
For the user's safety, 'squarebrackets' does check that the user doesn't accidentally add arguments that make no sense for that method (like specifying the `inv` argument when calling i_x).

---

aaa08_squarebrackets_slicev

On Index-Less Value-Based Sub-Set Operations

Description

This help page explains the details on the arguments used in the slicev_ methods and the countv function.

The Basic Idea

The basic idea is as follows.
Let `x` and `y` be 2 atomic vectors of the same length (but they don't have to be of the same type).
Let `v` be some atomic scalar of the same type as `y`.
Given the result `r` of the condition `y == v`, the basic idea is to perform the following sub-set operations:

```
slicev_x(x, y = y, v = v)            # ==> x[y == v]
slicev_set(x, y = y, v = v, rp = rp) # ==> x[y == v] <- rp
slicev_set(x, y = y, v = v, tf = tf) # ==> x[y == v] <- tf(x[y == v])
countv(y,v = v)                      # ==> sum(y == v)
```

The above is with the default argument specification `r = TRUE`.
Of course one can invert the relationship by specifying argument `r = FALSE`, to get something like the following:

```
slicev_x(x, y = y, v = v, r = FALSE)             # ==> x[y != v]
slicev_set(x, y = y, v = v, r = FALSE, rp = rp)  # ==> x[y != v] <- rp
slicev_set(x, y = y, v = v, r = FALSE, tf = tf)  # ==> x[y != v] <- tf(x[y != v])
countv(y, v = v, r = FALSE)                  # ==> sum(y != v)
```

And y is allowed to be the same vector as x, of course.

This basic idea, however, can become more complicated, depending on the atomic type of y, which is discussed in the next section.

Details per Atomic Type

Logical, Raw, Complex

For y of type logical, raw, and complex, slicev works exactly as explained in the previous section.
y and v must be of the same atomic type.

Numeric

For y of type integer or double (collectively referred to as "numeric"), the basic idea laid-out before still holds:
one can use atomic vector y and atomic scalar v to perform sub-set operations like
x[y == v].

But one may be more interested in a range of numbers, rather than one specific number (especially considering things like measurement error, and machine precision, and greater-than/larger-than relationships).
So for numeric y, one can also supply v of length **2**.
When length(v) == 2L, slicev_/ countv will check whether y is inside (or outside if r = FALSE) the bounded range given by v.
I.e. :

```
y >= v[1] & y <= v[2]  # if r = TRUE
y < v[1] | y > v[2]    # if r = FALSE
```

Note that y and v must both be numeric here, but they don't have to be the same type.
I.e. one can have y of type integer and v of type double, without problems.

Character

For y of type character, the basic idea is still to do something like x[y == v].

When searching for string v for sub-setting purposes, one may want to take into consideration things like different spelling, spacing, or even encodings of the same string.
Implementing every form of fuzzy matching or encoding matching is computationally intensive, and also quite beyond the scope of this package.
Instead, the user may supply a character vector v of arbitrary length, containing all the variations (in terms of spelling, spacing, encoding, or whatever) of all the strings to look for.

So if a vector is given for v (instead of a single string), the following check is performed:

```
y %in% v   # if r = TRUE
```

```
!y %in% v  # if r = FALSE
```

Factors

Technically, a factor has the type of `integer`, but it has special behaviour to the extend that it is treated differently in 'R'.
It is similarly treated by the `slicev_`/ `countv_` methods and functions.

When `y` is a factor, `v` can be given as:

- a single string (matching one of the levels of `y`);
- a single integer (matching one of the unique values of `unclass(y)`);
- a factor of length 1, with the same levels and level-ordering as `y`.

Note that factors with `NA` levels are not supported, and passing such a factor to `y` will result in an error.

Smaller Than, Greater Than

For numeric `y`, one can specify a range for `v`, as explained earlier.
But note one can also specify something like `v = c(-Inf, 4)`, which essentially corresponds to the condition `y <= 4`.
Thus, when `v` specifies a range, "greater-than" and "smaller-than" comparisons are also possible.
This also holds for `y` of type `complex`.

Handling NAs and NaN

We also have to handle the `NA`s and `NaN`s.
The `na` argument can be used to specify what to do when a `y` is `NA`.

When `na = FALSE`, all `NA` values of `y` are always ignored.
So these are not extracted (slicev_x), replaced (slicev_set), or counted (countv).

When `na = TRUE`, `NA` values of `y` are always included.
So these will be included in the extractions (slicev_x), replacements (slicev_set), and counts (countv).

One can also specify `na = NA`, which will ignore `v` completely, and explicitly look for `NA`s/`NaN`s in `y` instead - like so:

```
slicev_x(x, y = y, na = NA)                       # ==> x[is.na(y)]
slicev_x(x, y = y, na = NA, r = FALSE)            # ==> x[!is.na(y)]
slicev_set(x, y = y, na = NA, rp = rp)            # ==> x[is.na(y)] <- rp
slicev_set(x, y = y, na = NA, r = FALSE, rp = rp)  # ==> x[!is.na(y)] <- rp
slicev_set(x, y = y, na = NA, tf = tf)         # ==> x[is.na(y)] <- tf(x[is.na(y)])
slicev_set(x, y = y, na = NA, r = FALSE, tf = tf)  # ==> x[!is.na(y)] <- tf(x[!is.na(y)])
countv(y, na = NA)                                # ==> sum(is.na(y))
```

```
countv(y, na = NA, r = FALSE)                    # ==> sum(!is.na(y))
```

Handling NAs works the same for all atomic types.
For y of type complex, a value y[i] is considered NA if Re(y[i]) is NA/NaN and/or Im(y[i]) is NA/NaN.

Argument v is never allowed to contain NA/NaN.

From, To

Like the slice methods, one can specify the range within to perform the sub-set operations, using the from, to arguments.
For example, if you wish to extract all values of x for which holds that y != v, but **only** want the extractions between index 10 and 100, one can specify the following:
slicev_x(x, y = y, v = v, r = FALSE, from = 10, to = 100.

Just like slice, the from,to argument can also be used for reverse the order of the result, by specifying a higher value for from than for to.
The step-size in the slicev/countv functions is always 1L (or -1L if from > to).

Also like slice, from, to can be imaginary numbers also, as explained in cp_seq.

Inverting

countv() and slicev_set() do not have an "invert" argument, and likewise there is no slicev_wo() function.
One can only invert the sub-set condition, by specifying r = FALSE.
But r = FALSE only inverts the condition; it does not invert the range specified by from, to.

Ellipsis

The ellipsis (...) is intentionally placed right after the first argument (x in slicev_ and y in countv) to force the user to explicitly name all arguments, as doing so will avoid a lot of unnecessary confusion.

Examples

```
# basic idea ====
nms <- c(letters, LETTERS, month.abb, month.name) |> rep_len(1e6)
x <- mutatomic(1:1e6, names = nms)
head(x)
```

```
# memory efficient form of sum(x <= 10):
countv(x, v = c(-Inf, 10))

# extract all elements of x with the name "a":
slicev_x(x, y = names(x), v = "a") |> head()

# find all x smaller than or equal to 5, and replace with `-1000`:
slicev_set(x, y = x, v = c(-Inf, 5), rp = -1000L)
head(x, n = 10)


################################################################################
# Numeric range ====
#
x <- mutatomic(1:1e6)
head(x)
slicev_x(x, v= c(-Inf, 5)) # x[x <= 5]


################################################################################
# Character ====
#
x <- stringi::stri_rand_shuffle(rep("hello", 1e5))
head(x)
slicev_x(x, v = "hello") |> head() # find "hello"

# find 2 possible misspellings of "hello":
slicev_x(x, v = c("holle", "helol")) |> head()
```

`aaa09_squarebrackets_PassByReference`

Regarding Modification By Reference

Description

This help page describes how modification using "pass-by-reference" semantics is handled by the 'squarebrackets' package.

"Pass-by-reference" refers to modifying a mutable object, or a subset of a mutable object, without making any copies at all.

This help page does not explain all the basics of pass-by-reference semantics, as this is treated as prior knowledge.
All functions/methods in the 'squarebrackets' package with the word "set" in the name use pass-by-reference semantics.

Advantages and Disadvantages

The main advantage of pass-by-reference is that much less memory is required to modify objects, and modification is also generally faster.
But it does have several disadvantages.

First, the coercion rules are slightly different: see squarebrackets_coercion.

Second, if 2 or more variables refer to exactly the same object (i.e. have the same address), changing one variable also changes the other ones.
I.e. the following code,

```
x <- y <- mutatomic(1:16)
i_set(x, 1:6, rp = 8)
```

modifies not just `x`, but also `y`.
This is true even if one of the variables is locked (see bindingIsLocked).
I.e. the following code,

```
x <- mutatomic(1:16)
y <- x
lockBinding("y", environment())
i_set(x, i = 1:6, rp = 8)
```

modifies both `x` and `y` without error, even though `y` is a locked constant.

Mutable vs Immutable Classes

With the exception of environments, most of base R's S3 classes are treated as immutable:
Modifying an object in 'R' will make a copy of the object, something called 'copy-on-modify' semantics.

A prominent mutable S3 class is the `data.table` class, which is a mutable data.frame class, and supported by 'squarebrackets'.
Similarly, 'squarebrackets' adds a class for mutable atomic objects:
mutatomic.

Material vs Immaterial objects

Most objects in 'R' are material objects:
the values an object contains are actually stored in memory.
For example, given `x <- rnorm(1e6)`, `x` is a material object:
1 million values (decimal numbers, in this case) are actually stored in memory.

In contrast, ActiveBindings are immaterial:
They are objects that, when accessed, call a function to generate values on the fly, rather than actually storing values.

Since immaterial objects do not actually store the values in memory, the values obviously also

cannot be changed in memory.
Therefore, Pass-by-Reference semantics don't work on immaterial objects.

ALTREP

The mutatomic constructors (i.e. mutatomic, as.mutatomic, etc.) will automatically materialize ALTREP objects, to ensure consistent behaviour for 'pass-by-reference' semantics.

A `data.table` can have ALTREP columns.
A `data.tables` will coerce the column to a materialized column when it is modified, even by reference.

Mutability Rules With Respect To Recursive Objects

Lists are difficult objects in that they do not contain elements, they simply point to other objects, that one can access via a list.
When a recursive object is of a mutable class, all its subsets are treated as mutable, as long as they are part of the object.
On the other hand, When a recursive object is of an immutable class, its recursive subsets retain their original mutability.

Example 1: Mutable data.tables
A `data.table` is a mutable class.
So all columns of the `data.table` are treated as mutable;
There is no requirement to, for instance, first change all columns into the class of mutatomic to modify these columns by reference.

Example 2: Immutable lists
A regular `list` is an immutable class.
So the list itself is immutable, but the recursive subsets of the list retain their mutability.
If you have a list of `mutatomic` objects, for example, the mutatomic objects themselves remain mutable.
Therefore, the following pass-by-reference modification will work without issue:

```
x <- list(
 a = mutatomic(letters[1:10]),
 b = mutatomic(letters[11:20])
)
myref <- x$a
i_set(myref, 1, rp = "xxx")
```

Notice in the above code that `myref` has the same address as `x$a`, and is therefore not a copy of `x$a`.
Thus changing `myref` also changes `x$a`.
In other words: `myref` is what could be called a "**View**" of `x$a`.

Input Variable

Methods/functions that perform in-place modification by reference only works on objects that actually exist as an actual variable, similar to functions in the style of `some_function(x, ...) <- value`.
Thus things like any of the following,
`i_set(1:10, ...)`, `i_set(x$a, ...)`, or `i_set(base::letters)`,
will not and should not work.

Lock Binding

Mutable classes are, as the name suggests, meant to be mutable.
Locking the binding of a mutable object is fruitless.
To ensure an object cannot be modified by any of the methods/functions from 'squarebrackets', 2 things must be true:

- the object must be an immutable class.
- the binding must be **locked** (see lockBinding).

Protection

Due to the properties described above in this help page, 'squarebrackets' protects the user from do something like the following:

```
# letters = base::letters
i_set(letters, i = 1, rp = "XXX")
```

'squarebrackets' will give an error when running the code above, because:

1. most addresses in `baseenv()` are protected;
2. immutable objects are disallowed (you'll have to create a mutable object, which will create a copy of the original, thus keeping the original object safe from modification by reference);
3. locked bindings are disallowed.

Examples

```
# the following code demonstrates how locked bindings,
# such as `base::letters`,
# are being safe-guarded

x <- list(a = base::letters)
myref <- x$a # view of a list
address(myref) == address(base::letters) # TRUE: point to the same memory
bindingIsLocked("letters", baseenv()) # base::letters is locked ...
bindingIsLocked("myref", environment()) # ... but this pointer is not!
```

```
if(requireNamespace("tinytest")) {
  tinytest::expect_error(
    i_set(myref, i = 1, rp = "XXX") # this still gives an error though ...
  )
}

is.mutatomic(myref) # ... because it's not of class `mutatomic`


x <- list(
  a = as.mutatomic(base::letters) # `as.mutatomic()` makes a copy
)
myref <- x$a # view of a list
address(myref) == address(base::letters) # FALSE: it's a copy
i_set(
  myref, i = 1, rp = "XXX"  # modifies x, does NOT modify `base::letters`
)
print(x) # x is modified
base::letters # but this still the same
```

`aaa10_squarebrackets_coercion`

Auto-Coercion Rules for Mutable Objects

Description

This help page describes the auto-coercion rules of the mutable classes, as they are handled by the 'squarebrackets' package.
This useful information for users who wish to intend to employ Pass-by-Reference semantics as provided by 'squarebrackets'.

mutatomic

coercion_through_copy: YES
coercion_by_reference: NO
Mutable atomic objects are automatically coerced to fit the modified subset values, when modifying through copy, just like regular atomic classes.
For example, replacing one or multiple values in an integer vector (type `int`) with a decimal number (type `dbl`) will coerce the entire vector to type `dbl`.

Replacing or transforming subsets of mutable atomic objects **by reference** does not support coercion. Thus, for example, the following code,

```
x <- mutatomic(1:16)
i_set(x, i = 1:6, rp = 8.5)
#> coercing replacement to integer
print(x)
```

```
#>  [1]  8  8  8  8  8  8  7  8  9 10 11 12 13 14 15 16
#> mutatomic
#> typeof:  integer
```

gives `c(rep(8, 6) 7:16)` instead of `c(rep(8.5, 6), 7:16)`, because `x` is of type `integer`, so `rp` is interpreted as type `integer` also.

data.table, when replacing/transforming whole columns

coercion_through_copy: YES
coercion_by_reference: YES
A data.table is actually a list made mutable, where each column is itself a list. As such, replacing/transforming whole columns using `data.table::set()`, without specifying rows (not even `i = 1:nrow(x)`), allows completely changing the type of the column.

data.table, when partially replacing/transforming columns

coercion_through_copy: YES
coercion_by_reference: NO
If rows are specified in the `data.table::set()` function (and functions that internally use `data.table::set()`), and thus not all values of columns but parts(i.e. rows) of columns are replaced, no auto-coercion takes place.
I.e.: replacing/transforming a value in an integer (`int`) column to become `1.5`, will not coerce the column to the decimal type (`dbl`); instead, the replacement value `1.5` is coerced to integer `1`.

Using R's native copy-on-modify semantics (for example by changing a `data.table` into a `data.frame`) allows for coercion even when partially replacing/transforming columns.

Views of Lists

Regular lists are treated as immutable by 'squarebrackets'.
But remember that a list is a (potentially hierarchical) structure of references to other objects.
Thus, even if a list itself is not treated as mutable, subsets of a list which are themselves mutable classes, are mutable.
For example, if you have a list of `data.table` objects, the data.tables themselves are mutable.
Therefore, the following will work:

```
x <- list(
 a = mutatomic(letters[1:10]),
 b = mutatomic(letters[11:20])
)
myref <- x$a
i_set(myref, 1, rp = "xxx")
```

Notice in the above code that `myref` is not a copy of `x$a`, since they have the same address.
Thus changing `myref` also changes `x$a`.
In other words: `myref` is what could be called a "view" of `x$a`.
Notice also that i_set`(x$a, ...)` will not work.
This is because stopifnot_ma_safe2mutate will give an error if `x` is not an **actual variable**, similar to in-place functions in the style of `` `myfun()<-` ``.

The auto-coercion rules of Views of Lists, depends entirely on the object itself.
Thus if the View is a data.table, coercion rules of data.tables apply.
And if the View is a mutatomic object, coercion rules of mutatomic objects apply, etc.

Examples

```
# Coercion examples - mutatomic ====

x <- as.mutatomic(1:16)
i_set(x, i = 1:6, rp = 8.5) # 8.5 coerced to 8, because `x` is of type `integer`
print(x)

################################################################################

# Coercion examples - data.table - whole columns ====

# ss2_mod():
obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_mod(
  obj, vars = is.numeric,
  tf = sqrt # SAFE: row=NULL & obs = NULL, so coercion performed
)

# ss2_set():
ss2_set(
  obj, vars = is.numeric,
  tf = sqrt # SAFE: row=NULL & obs = NULL, so coercion performed
)
str(obj)

################################################################################


# Coercion examples - data.table - partial columns ====

# ss2_mod():
obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)

ss2_mod(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # SAFE: coercion performed
```

```
)

# ss2_set():
obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_set(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt
  # WARNING: sqrt() results in `dbl`, but columns are `int`, so decimals lost
)
print(obj)

obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj)
dt_setcoe(obj, vars = is.numeric, v = as.numeric)
str(obj)
ss2_set(obj,
  obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # SAFE: coercion performed by dt_setcoe(); so no warnings
)
print(obj)


################################################################################

# View of List ====

x <- list(
 a = data.table::data.table(cola = 1:10, colb = letters[1:10]),
 b = data.table::data.table(cola = 11:20, colb = letters[11:20])
)
print(x)
myref <- x$a
address(myref) == address(x$a) # they are the same
ss2_set(myref, vars = "cola", tf = \(x)x^2)
print(x) # notice x has been changed
```

---

cp_seq *Construct Parameters for a Sequence Based on Margins*

Description

cp_seq() returns a list of parameters to construct a sequence based on the margins of an object. It is internally used by the idx_r function and slice method.

Usage

```
cp_seq(x, m = 0L, from = NULL, to = NULL, by = 1L)
```

Arguments

x	the object for which to compute margin-based sequence parameters.
m	integer or complex, giving the margin(s). For non-dimensional objects or for flat indices, specify m = 0L.
from	integer or complex, of the same length as m or of length 1, specifying the from point.
to	integer or complex, of the same length as m or of length 1, specifying the **maximally allowed** end value.
by	integer, of the same length as m or of length 1, specifying the step size.

Value

A list of the following elements:

$start:
The actual starting point of the sequence.
This is simply from translated to regular numeric.

$end:
The **actual** ending point of the sequence.
This is not the same as to.
For example, the following code:

```
seq(from = 1L, to = 10L, by = 2L)
#> [1] 1 3 5 7 9
```

specifies to = 10L.
But the sequence doesn't actually end at 10; it ends at 9.
Therefore, cp_seq(x, m, 1, 10, 2) will return end = 9, not end = 10.
This allows the user to easily predict where an sequence given in idx_r/slice will actually end.

$by:
This will give by, but with it's sign adjusted, if needed.

$length.out:
The actual vector lengths the sequences would be, given the translated parameters.

Arguments Details

Multiple dimensions at once

The cp_seq function can construct the sequence parameters needed for multiple dimensions at once, by specifying a vector for m.
The lengths of the other arguments are then recycled if needed.

Using only by

If from, to are not specified, using by will construct the following sequence:
If by is positive, seq.int(1L, n, by).
If by is negative, seq.int(n, 1L, by).

Where n is the maximum index (i.e. `length(x)` or `dim(x)[m]`, depending on the situation).

Using `from, to, by`
If `from, to, by` are all specified, `by` is stored as `abs(by)`, and the sign of `by` is automatically adjusted to ensure a sensible sequence is created.

Examples

```
x <- data.frame(
  a = 1:10, b = letters[1:10], c = factor(letters[1:10]), d = -1:-10
)
print(x)
ind1 <- idx_r(x, 1, 2, 2* -1i) # rows 2:(nrow(x)-1)
ss2_x(x, ind1, 1L) # extract the row range

x <- array(1:125, c(5,5,5))
d <- 1:3
s <- idx_r(x, d, 2, 2* -1i) # 2:(n-1) for every dimension
ss_x(x, s = s, d = d) # same as x[ 2:4, 2:4, 2:4, drop = FALSE]

x <- letters
x[idx_r(x, 0, 2, 2* -1i)]
```

`developer_ci` *Construct Indices*

Description

These functions construct flat or dimensional indices.

- `ci_flat()` constructs an integer vector flat indices.
- `ci_margin()` constructs an integer vector of indices for one particular dimension margin.
- `ci_sub()` constructs a list of integer subscripts.
- `ci_df()` is the same as `ci_margin()`, except it is specifically designed for data.frame-like objects.
  It is a separate function, because things like `dimnames(x)[1]` and `rownames(x)` do not always return the same output for certain data.frame-like objects.
- `ci_obs()` and `ci_vars()` construct row and column indices, respectively, data.frame-like objects.

Usage

```
ci_flat(
  x,
  i,
  inv = FALSE,
```

```
  chkdup = FALSE,
  uniquely_named = FALSE,
  .abortcall = sys.call()
)

ci_margin(
  x,
  slice,
  margin,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = FALSE,
  .abortcall = sys.call()
)

ci_sub(
  x,
  s,
  d,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = FALSE,
  .abortcall = sys.call()
)

ci_df(
  x,
  slice,
  margin,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = TRUE,
  .abortcall = sys.call()
)

ci_obs(
  x,
  obs,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = TRUE,
  .abortcall = sys.call()
)

ci_vars(
  x,
  vars,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = TRUE,
  .abortcall = sys.call()
)
```

Arguments

x	the object for which the indices are meant.
i, s, d, slice, margin, obs, vars, inv	See squarebrackets_indx_args.
chkdup	see squarebrackets_options. for performance: set to FALSE
uniquely_named	Boolean, indicating if the user knows a-priori that the relevant names of x are unique. If set to TRUE, speed may increase. But specifying TRUE when the relevant names are not unique will result in incorrect output.
.abortcall	environment where the error message is passed to.

Value

An integer vector of constructed indices.

Examples

```
x <- matrix(1:25, 5, 5)
colnames(x) <- c("a", "a", "b", "c", "d")
print(x)

bool <- sample(c(TRUE, FALSE), 5, TRUE)
int <- 1:4
chr <- c("a", "a")
cplx <- 1:4 * -1i
tci_bool(bool, nrow(x))
tci_int(int, ncol(x), inv = TRUE)
tci_chr(chr, colnames(x))
tci_cplx(cplx, nrow(x))

ci_flat(x, 1:10 * -1i)
ci_margin(x, 1:4, 2)
ci_sub(x, n(1:5 * -1i, 1:4), 1:2)
```

---

developer_tci *Type Cast Indices*

Description

These functions typecast indices to proper integer indices.

Usage

```
tci_bool(indx, n, inv = FALSE, .abortcall = sys.call())

tci_int(indx, n, inv = FALSE, chkdup = FALSE, .abortcall = sys.call())

tci_chr(
  indx,
  nms,
  inv = FALSE,
  chkdup = FALSE,
  uniquely_named = FALSE,
  .abortcall = sys.call()
)

tci_cplx(indx, n, inv = FALSE, chkdup = FALSE, .abortcall = sys.call())
```

Arguments

indx	the indices to typecast
n	the relevant size, when typecasting integer or logical indices. Examples: • If the target is row indices, input nrow for n. • If the target is flat indices, input the length for n.
inv	Boolean, indicating if the indices should be inverted. See squarebrackets_indx_args.
.abortcall	environment where the error message is passed to.
chkdup	see squarebrackets_options. for performance: set to FALSE
nms	the relevant names, when typecasting character indices. Examples: • If the target is row indices, input row names for nms. • If the target is flat indices, input flat names for nms.
uniquely_named	Boolean, indicating if the user knows a-priori that the relevant names of x are unique. If set to TRUE, speed may increase. But specifying TRUE when the relevant names are not unique will result in incorrect output.

Value

An integer vector of type-cast indices.

Examples

```
x <- matrix(1:25, 5, 5)
colnames(x) <- c("a", "a", "b", "c", "d")
print(x)

bool <- sample(c(TRUE, FALSE), 5, TRUE)
```

```
int <- 1:4
chr <- c("a", "a")
cplx <- 1:4 * -1i
tci_bool(bool, nrow(x))
tci_int(int, ncol(x), inv = TRUE)
tci_chr(chr, colnames(x))
tci_cplx(cplx, nrow(x))

ci_flat(x, 1:10 * -1i)
ci_margin(x, 1:4, 2)
ci_sub(x, n(1:5 * -1i, 1:4), 1:2)
```

---

dt *Functional Forms of data.table Operations*

Description

Functional forms of special data.table operations.
These functions do not use Non-Standard Evaluation.
These functions also benefit from the security measures that 'squarebrackets' implements for the pass-by-reference semantics.

- `dt_aggregate()` aggregates a data.table or tidytable, and returns the aggregated copy.
- `dt_setcoe()` coercively transforms columns of a data.table or tidytable using pass-by-reference semantics.
- `dt_setrm()` removes columns of a data.table or tidytable using pass-by-reference semantics.
- `dt_setadd(x, new)` adds the columns from data.table/tidytable `new` to data.table/tidytable `x`, thereby modifying `x` using pass-by-reference semantics.
- `dt_setreorder()` reorders the rows and/or variables of a `data.table` using pass-by-reference semantics.

Usage

```
dt_aggregate(x, SDcols = NULL, f, by, order_by = FALSE)

dt_setcoe(
  x,
  vars = NULL,
  inv = FALSE,
  v,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

dt_setrm(
  x,
  vars = NULL,
  inv = FALSE,
```

```
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

dt_setadd(x, new)

dt_setreorder(x, roworder = NULL, varorder = NULL)
```

Arguments

x	a data.table or tidytable.
SDcols	atomic vector, giving the columns to which the aggregation function f() is to be applied on.
f	the aggregation function
by	atomic vector, giving the grouping columns.
order_by	Boolean, indicating if the aggregated result should be ordered by the columns specified in by.
vars, inv	see squarebrackets_indx_args. Duplicates are not allowed.
v	the coercive transformation function
chkdup	see squarebrackets_options. for performance: set to FALSE
new	a data.frame-like object. It must have column names that do not already exist in x.
roworder	a integer vector of the same length as nrow(x), giving the order in which the rows are to be re-order. Internally, this numeric vector will be turned into an order using order, thus ensuring it is a strict permutation of 1:nrow(x).
varorder	integer or character vector of the same length as ncol(x), giving the new column order. See data.table::setcolorder.

Details

dt_setreorder(x, roworder = roworder) internally creates a new column to reorder the data.table by, and then removes the new column.
The column name is randomized, and extra care is given to ensure it does not overwrite any existing columns.

Value

For dt_aggregate():
The aggregated data.table object.

For the rest of the functions:
Returns: VOID. These functions modify the object by reference.
Do not use assignments like x <- dt_setcoe(x, ...).
Since these functions return void, you'll just get NULL.

Examples

```
# dt_aggregate on sf-data.table ====

if(requireNamespace("sf")) {
  x <- sf::st_read(system.file("shape/nc.shp", package = "sf"))
  x <- data.table::as.data.table(x)

  x$region <- ifelse(x$CNTY_ID <= 2000, 'high', 'low')
  d.aggr <- dt_aggregate(
    x, SDcols = "geometry", f= sf::st_union, by = "region"
  )

  head(d.aggr)
}



################################################################################


# dt_setcoe ====

obj <- data.table::data.table(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_set(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # WARNING: sqrt() results in `dbl`, but columns are `int`, so decimals lost
)
str(obj)
obj <- data.table::data.table(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
dt_setcoe(obj, vars = is.numeric, v = as.numeric) # integers are now numeric
str(obj)
ss2_set(obj,
  obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # SAFE: coercion performed; so no warnings
)
str(obj)


################################################################################


# dt_setrm ====

obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj)
dt_setrm(obj, vars = 1)
str(obj)

obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
str(obj)
dt_setrm(obj, vars = is.numeric)
```

```
str(obj)


################################################################################


# dt_setadd ====

obj <- data.table::data.table(
  a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10])
)
new <- data.table::data.table(
  e = sample(c(TRUE, FALSE), 10, TRUE),
  f = sample(c(TRUE, FALSE), 10, TRUE)
)
dt_setadd(obj, new)
print(obj)



################################################################################


# dt_setreorder====

n <- 1e4
obj <- data.table::data.table(
  a = 1L:n, b = n:1L, c = as.double(1:n), d = as.double(n:1)
)
dt_setreorder(obj, roworder = n:1)
head(obj)
dt_setreorder(obj, varorder = ncol(obj):1)
head(obj)
```

`i2_rec` *Access, Replace, Transform, Delete, or Extend Recursive Subsets*

Description

The `i2_rec()` and `i2_recin()` methods are essentially convenient wrappers around `[[` and `[[<-`, respectively.
Unlike `[[` and `[[<-`, these are actually S3 methods, so package authors can create additional method dispatches.

`i2_rec()` will access recursive subsets of lists.

`i2_recin()` can do the following things:

- replace or transform recursive subsets of a list, using R's default Copy-On-Modify semantics, by specifying the `rp` or `tf` argument, respectively.
- delete a recursive subset of a list, using R's default Copy-On-Modify semantics, by specifying argument `rp = NULL`.

- extending a list with additional recursive elements, using R's default Copy-On-Modify semantics.
  This is done by specifying an out-of-bounds index in argument `rec`, and entering the new values in argument `rp`.
  Note that adding surface level elements of a dimensional list will delete the dimension attributes of that list.

Usage

```
i2_rec(x, ...)

## Default S3 method:
i2_rec(x, rec, ...)

i2_recin(x, ...)

## Default S3 method:
i2_recin(x, rec, ..., rp, tf)
```

Arguments

`x`	a list, or list-like object.
`...`	see squarebrackets_method_dispatch.
`rec`	a strictly positive integer vector or character vector, of length `p`, such that `i2_rec(x, rec)` is equivalent to `x[[ rec[1] ]]...[[ rec[p] ]]`, providing all but the final indexing results in a list. When on a certain subset level of a nested list, multiple subsets with the same name exist, only the first one will be selected when performing recursive indexing by name, since recursive indexing can only select a single element. `NA, NaN, Inf, -Inf` are not valid values for `rec`.
`rp`	optional, and allows for multiple functionalities: • In the simplest case, performs `x[[rec]] <- rp`, using R's default semantics. Since this is a replacement of a recursive subset, `rp` does not necessarily have to be a list itself; `rp` can be any type of object. • Specifying `rp = NULL` will **delete** (recursive) subset `sb(x, rec)`. To specify actual `NULL` instead of deleting a subset, use `rp = list(NULL)`. • When `rec` is an integer, and specifies an out-of-bounds subset, `i2_recin()` will add value `rp` to the list. Any empty positions in between will be filled with `NA`. • When `rec` is character, and specifies a non-existing name, `i2_recin()` will add value `rp` to the list as a new element at the end.
`tf`	an optional function. If specified, performs `x[[rec]] <- tf(x[[rec]])`, using R's default Copy-On-Modify semantics. Does not support extending a list like argument `rp`.

Details

Since recursive objects are references to other objects, extending a list or deleting an element of a list does not copy the entire list, in contrast to atomic vectors.

Value

For `i2_rec()`:
Returns the recursive subset.

For `i2_recin(..., rp = rp)`:
Returns VOID, but replaces, adds, or deletes the specified recursive subset, using R's default Copy-On-Modify semantics.

For `i2_recin(..., tf = tf)`:
Returns VOID, but transforms the specified recursive subset, using R's default Copy-On-Modify semantics.

Examples

```
lst <- list(
  A = list(
    A = list(A = "AAA", B = "AAB"),
    A = list(A  = "AA2A", B = "AA2B"),
    B = list(A = "ABA", B = "ABB")
  ),
  B = list(
    A = list(A = "BAA", B = "BAB"),
    B = list(A = "BBA", B = "BBB")
  ),
  C = list(
    A = 1:10,
    B = 11:20
  )
)

################################################################################

# access recursive subsets ====

i2_rec(lst, c(1,2,2)) # this gives "AA2B"
i2_rec(lst, c("A", "B", "B")) # this gives "ABB"
i2_rec(lst, c(2,2,1)) # this gives "BBA"
i2_rec(lst, c("B", "B", "A")) # this gives "BBA"


################################################################################

# replace recursive subset with R's default in-place semantics ====

# replace "AAB" using R's default in-place semantics:
i2_recin(
  lst, c("A", "A", "B"),
  rp = "THIS IS REPLACED WITH IN-PLACE SEMANTICS"
)
```

```
print(lst)


################################################################################

# transform recursive subsets with R's default in-place semantics ====

i2_recin(lst, c("C", "A"), tf = \(x)x^2) # transforms lst$C$A

print(lst)


################################################################################

# add/remove new recursive subsets with R's default in-place semantics ====

i2_recin(lst, c("C", "D"), rp = "NEW VALUE") # adds lst$C$D
print(lst)

i2_recin(lst, c("C", "A"), rp = NULL) # removes lst$C$A
print(lst) # notice lst$C$A is GONE


################################################################################

# Modify View of List By Reference ====

x <- list(
 a = data.table::data.table(cola = 1:10, colb = letters[1:10]),
 b = data.table::data.table(cola = 11:20, colb = letters[11:20])
)
print(x)
myref <- i2_rec(x, "a")
address(myref) == address(x$a) # they are the same
ss2_set(myref, vars = "cola", tf = \(x)x^2)
print(x) # notice x has been changed
```

`idx` *Convert/Translate Indices (for Copy-On-Modify Substitution)*

Description

The `idx()` method converts indices.
The type of output depends on the type of input index arguments given:

- `idx(x, i = i, ...)` converts linear indices to a strictly positive integer vector of linear indices.
- `idx(x, s = s, d = d, ...)` converts dimensional indices to a strictly positive integer vector of linear indices.
- `idx(x, slice = slice, margin = margin, ...)` converts indices of one dimension to a strictly positive integer vector of indices for that specific dimension.

Vectors (both atomic and recursive) only have index argument `i`.
Data.frame-like objects only have the `slice, margin` argument pair.
Arrays (both atomic and recursive) have the `s, d` argument pair, as well as the `i` argument and the `slice, margin` argument pair.

The result of the `idx()` method can be used inside the regular square-brackets operators.
For example like so:

```
x <- array(...)
my_sub2ind <- idx(x, s, d)
x[my_sub2ind] <- value

y <- data.frame(...)
rows <- idx(y, 1:10, 1, inv = TRUE)
cols <- idx(y, c("a", "b"), 2)
y[rows, cols] <- value
```

thus allowing the user to benefit from the convenient index translations from 'squarebrackets', whilst still using R's default copy-on-modification semantics (instead of the semantics provided by 'squarebrackets').

Usage

```
idx(x, ...)

## Default S3 method:
idx(x, i, inv = FALSE, ..., chkdup = getOption("squarebrackets.chkdup", FALSE))

## S3 method for class 'array'
idx(
  x,
  s = NULL,
  d = 1:ndim(x),
  slice = NULL,
  margin = NULL,
  i = NULL,
  inv = FALSE,
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## S3 method for class 'data.frame'
idx(
  x,
  slice,
  margin,
  inv = FALSE,
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)
```

Arguments

x	vector, matrix, array, or data.frame; both atomic and recursive objects are supported.
...	see squarebrackets_method_dispatch.
i, s, d, margin, slice, inv	See squarebrackets_indx_args. Duplicates are not allowed.
chkdup	see squarebrackets_options. for performance: set to FALSE

Value

For `idx(x, i = i, ...)` and `idx(x, s = s, d = d, ...)`:
A strictly positive integer vector of flat indices.

For `idx(x, margin = margin, slice = slice, ...)`:
A strictly positive integer vector of indices for the dimension specified in `margin`.

Examples

```
# atomic ====

x <- 1:10
x[idx(x, \(x)x>5)] <- -5
print(x)

x <- array(1:27, dim = c(3,3,3))
x[idx(x, n(1:2, 1:2), c(1,3))] <- -10
print(x)


################################################################################


# recursive ====

x <- as.list(1:10)
x[idx(x, \(x)x>5)] <- -5
print(x)

x <- array(as.list(1:27), dim = c(3,3,3))
x[idx(x, n(1:2, 1:2), c(1,3))] <- -10
print(x)


x <- data.frame(
  a = sample(c(TRUE, FALSE, NA), 10, TRUE),
  b = 1:10,
  c = rnorm(10),
  d = letters[1:10],
  e = factor(letters[11:20])
```

```
)
rows <- idx(x, 1:5, 1, inv = TRUE)
cols <- idx(x, c("b", "a"), 2)
x[rows, cols] <- NA
print(x)
```

---

idx_by *Compute Grouped Indices*

Description

Given:

- a sub-set function f;
- an object x with its margin m;
- and a grouping factor grp;

the idx_by() function takes indices **per group** grp.
The result of idx_by() can be supplied to the indexing arguments (see squarebrackets_indx_args) to perform **grouped** subset operations.

Usage

```
idx_by(x, m, f, grp, parallel = FALSE, mc.cores = 1L)
```

Arguments

x	the object from which to compute the indices.
m	a single non-negative integer giving the margin for which to compute indices. For flat indices or for non-dimensional objects, use m = 0L.
f	a subset function to be applied per group on indices. If m == 0L, indices is here defined as setNames(1:length(x), names(x)). If m > 0L, indices is here defined as setNames(1:dim(x)[m], dimnames(x)[[m]]). The function must produce a character or integer vector as output. For example, to subset the last element per group, specify: f = last
grp	a factor giving the groups.
parallel, mc.cores	see BY.

Value

A vector of indices.

Examples

```
# vectors ====
(a <- 1:20)
(grp <- factor(rep(letters[1:5], each = 4)))

# get the last element of `a` for each group in `grp`:
s <- list(idx_by(a, 0L, last, grp))
ss_x(cbind(a, grp), s, 1L)


# data.frame ====
x <- data.frame(
  a = sample(1:20),
  b = letters[1:20],
  group = factor(rep(letters[1:5], each = 4))
)
print(x)
# get the first row for each group in data.frame `x`:
row <- idx_by(x, 1, first, x$group)
ss2_x(x, row, 1L)
# get the first row for each group for which a > 10:
x2 <- ss2_x(x, obs = ~ a > 10)
row <- na.omit(idx_by(x2, 1, first, x2$group))
ss2_x(x2, row, 1L)
```

`idx_ord_v` *Compute Ordered Indices*

Description

Computes ordered indices. Similar to order, except the user must supply a vector, a list of equal-length vectors, a data.frame or a matrix (row-wise and column-wise are both supported), as the input.

For a vector `x`,
`idx_ord_v(x)` is equivalent to
order`(x)`.

For a data.frame or a list of equal-length vectors `x`, with `p` columns/elements,
`idx_ord_df(x)` is equivalent to
`order(x[[1]], ..., x[[p]])`.

For a matrix (or array) `x` with `p` rows,
`idx_ord_m(x, margin = 1)` is equivalent to
`order(x[1, ], ..., x[p, ], ...)`.

For a matrix (or array) `x` with `p` columns,
`idx_ord_m(x, margin = 2)` is equivalent to
`order(x[, 1], ..., x[, p], ...)`.

Note that these are merely convenience functions, and that these are actually slightly slower than order (except for `idx_ord_v()`), due to the additional functionality.

Usage

```
idx_ord_v(
  x,
  na.last = TRUE,
  decr = FALSE,
  method = c("auto", "shell", "radix")
)

idx_ord_m(
  x,
  margin,
  na.last = TRUE,
  decr = FALSE,
  method = c("auto", "shell", "radix")
)

idx_ord_df(
  x,
  na.last = TRUE,
  decr = FALSE,
  method = c("auto", "shell", "radix")
)
```

Arguments

`x`	a vector, data.frame, or array
`na.last`, `method`	see order and sort.
`decr`	see argument `decreasing` in order
`margin`	the margin over which to cut the matrix/array into vectors. I.e. `margin = 1L` will cut `x` into individual rows, and apply the order on those rows. And `margin = 2L` will cut `x` into columns, etc.

Value

See order.

Examples

```
x <- sample(1:10)
order(x)
idx_ord_v(x)
idx_ord_m(rbind(x, x), 1)
idx_ord_m(cbind(x, x), 2)
idx_ord_df(data.frame(x, x))
```

idx_r *Compute Integer Index Range*

Description

`idx_r()` computes integer index range(s).

Usage

```
idx_r(x, m = 0L, from = NULL, to = NULL, by = 1L)
```

Arguments

`x`	the object for which to compute subset indices.
`m`, `from`, `to`, `by`	see cp_seq.

Value

If `length(m) == 1L`: a vector of numeric indices.

If `length(m) > 1L`: a list of the same length as `m`, containing numeric vectors of indices.

Examples

```
x <- data.frame(
  a = 1:10, b = letters[1:10], c = factor(letters[1:10]), d = -1:-10
)
print(x)
ind1 <- idx_r(x, 1, 2, 2* -1i) # rows 2:(nrow(x)-1)
ss2_x(x, ind1, 1L) # extract the row range

x <- array(1:125, c(5,5,5))
d <- 1:3
s <- idx_r(x, d, 2, 2* -1i) # 2:(n-1) for every dimension
ss_x(x, s = s, d = d) # same as x[ 2:4, 2:4, 2:4, drop = FALSE]

x <- letters
x[idx_r(x, 0, 2, 2* -1i)]
```

indx_x *Exported Utilities*

Description

Exported utilities.
Usually the user won't need these functions.

Usage

```
indx_x(i, x, xnames, xsize)

indx_wo(i, x, xnames, xsize)
```

Arguments

i	See squarebrackets_indx_args.
x	a vector, vector-like object, factor, data.frame, data.frame-like object, or a list.
xnames	names or dimension names
xsize	length or dimension size

Value

The subsetted object.

Examples

```
x <- 1:10
names(x) <- letters[1:10]
indx_x(1:5, x, names(x), length(x))
indx_wo(1:5, x, names(x), length(x))
```

i_mod *Method to Return a Copy of an Object With Modified Subsets*

Description

Methods to return a copy of an object with modified subsets.
For modifying subsets using R's default copy-on-modification semantics, see idx.

Usage

```
i_mod(x, ...)

i2_mod(x, ...)

ss_mod(x, ...)

ss2_mod(x, ...)

## Default S3 method:
i_mod(
  x,
  i = NULL,
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
ss_mod(
  x,
  s = NULL,
  d = 1:ndim(x),
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
i2_mod(
  x,
  i = NULL,
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE),
  .lapply = lapply
)

## Default S3 method:
ss2_mod(
  x,
  s = NULL,
  d = 1:ndim(x),
  inv = FALSE,
  ...,
  rp,
```

```
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE),
  .lapply = lapply
)

## S3 method for class 'data.frame'
ss2_mod(
  x,
  s = NULL,
  d = 1:2,
  obs = NULL,
  vars = NULL,
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE),
  .lapply = lapply
)
```

Arguments

x	see squarebrackets_supported_structures.
...	see squarebrackets_method_dispatch.
i, s, d, obs, vars, inv	See squarebrackets_indx_args. An empty index selection returns the original object unchanged.
rp, tf, .lapply	see squarebrackets_modify.
chkdup	see squarebrackets_options. for performance: set to FALSE

Details

Transform or Replace
Specifying argument `tf` will transform the subset.
Specifying `rp` will replace the subset.
One cannot specify both `tf` and `rp`. It's either one set or the other.

Value

A copy of the object with replaced/transformed values.

Examples

```
# atomic objects ====

obj <- matrix(1:16, ncol = 4)
colnames(obj) <- c("a", "b", "c", "a")
```

```
print(obj)
rp <- -1:-9
ss_mod(obj, n(1:3), 1:ndim(obj), rp = rp)
# above is equivalent to  obj[1:3, 1:3] <- -1:-9; obj
i_mod(obj, i = \(x)x<=5, rp = -1:-5)
# above is equivalent to  obj[obj <= 5] <- -1:-5; obj
ss_mod(obj, n("a"), 2L, rp = -1:-8)
# above is equivalent to  obj[, which(colnames(obj) %in% "a")] <- -1:-8; obj
ss_mod(obj, n(1:3), 1:ndim(obj), tf = \(x) -x)
# above is equivalent to  obj[1:3, 1:3] <- (-1 * obj[1:3, 1:3]); obj
i_mod(obj, i = \(x)x <= 5, tf = \(x) -x)
# above is equivalent to  obj[obj <= 5] <- (-1 * obj[obj <= 5]); obj

obj <- array(1:64, c(4,4,3))
print(obj)
ss_mod(obj, n(1:3, 1:2), c(1,3), rp = -1:-24)
# above is equivalent to obj[1:3, , 1:2] <- -1:-24
i_mod(obj, i = \(x)x <= 5, rp = -1:-5)
# above is equivalent to obj[obj <= 5] <- -1:-5

################################################################################


# lists ====

obj <- list(a = 1:10, b = letters[1:11], c = 11:20)
print(obj)
i2_mod(obj, "a", rp = list(1L))
# above is equivalent to  obj[["a"]] <- 1L; obj
i2_mod(obj, is.numeric, rp = list(-1:-10, -11:-20))
# above is equivalent to  obj[which(sapply(obj, is.numeric))] <- list(-1:-10, -11:-20); obj

obj <- rbind(
  lapply(1:4, \(x)sample(c(TRUE, FALSE, NA))),
  lapply(1:4, \(x)sample(1:10)),
  lapply(1:4, \(x)rnorm(10)),
  lapply(1:4, \(x)sample(letters))
)
colnames(obj) <- c("a", "b", "c", "a")
print(obj)
ss2_mod(obj, n(1:3), 1:ndim(obj),rp = n(-1))
# above is equivalent to obj[1:3, 1:3] <- list(-1)
i2_mod(obj, i = is.numeric, rp = n(-1))
# above is equivalent to obj[sapply(obj, is.numeric)] <- list(-1)
ss2_mod(obj, n("a"), 2L, rp = n(-1))
# above is equivalent to
# obj[, lapply(c("a", "a"), \(i) which(colnames(obj) == i)) |> unlist()] <- list(-1)


obj <- array(as.list(1:64), c(4,4,3))
print(obj)
ss2_mod(obj, n(1:3, 1:2), c(1,3), rp = as.list(-1:-24))
# above is equivalent to obj[1:3, , 1:2] <- as.list(-1:-24)
i2_mod(obj, i = \(x) x <= 5, rp = as.list(-1:-5))
# above is equivalent to obj[sapply(onj, \(x) x <= 5)] <- as.list(-1:-5)
```

```
################################################################################

# data.frame-like objects  - whole columns ====

obj <- data.frame(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_mod(
  obj, vars = is.numeric,
  tf = sqrt
)

################################################################################

# data.frame-like objects  - partial columns ====

obj <- data.frame(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)

ss2_mod(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt
)
ss2_mod(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt
)
ss2_mod(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt
)
```

`i_set` *Methods to Modify Subsets of a Mutable Object By Reference*

Description

Methods to replace or transform a subset of a supported mutable object using pass-by-reference semantics.

Usage

```
i_set(x, ...)

i2_set(x, ...)

ss_set(x, ...)

ss2_set(x, ...)
```

```
## Default S3 method:
i_set(
  x,
  i = NULL,
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
ss_set(
  x,
  s = NULL,
  d = 1:ndim(x),
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
i2_set(x, ...)

## S3 method for class 'data.table'
ss2_set(
  x,
  s = NULL,
  d = 1:2,
  obs = NULL,
  vars = NULL,
  inv = FALSE,
  ...,
  rp,
  tf,
  chkdup = getOption("squarebrackets.chkdup", FALSE),
  .lapply = lapply
)
```

Arguments

x	a **variable** belonging to one of the supported mutable classes.
...	see squarebrackets_method_dispatch.
i, s, d, obs, vars, inv	See squarebrackets_indx_args. An empty index selection leaves the original object unchanged.
rp, tf, .lapply	see squarebrackets_modify.

chkdup	see squarebrackets_options. for performance: set to FALSE

Details

Transform or Replace

Specifying argument `tf` will transform the subset. Specifying `rp` will replace the subset. One cannot specify both `tf` and `rp`. It's either one set or the other.

Value

Returns: VOID. This method modifies the object by reference.
Do not use assignments like `x <- i_set(x, ...)`.
Since this function returns void, you'll just get `NULL`.

Examples

```
# mutatomic objects ====

gen_mat <- function() {
  obj <- as.mutatomic(matrix(1:16, ncol = 4))
  colnames(obj) <- c("a", "b", "c", "a")
  return(obj)
}

obj <- obj2 <- gen_mat()
print(obj)

ss_set(obj, n(1:3), 1:ndim(obj), rp = -1:-9)
print(obj2)
# above is like x[1:3, 1:3] <- -1:-9, but using pass-by-reference

obj <- obj2 <- gen_mat()
obj

i_set(obj, i = \(x) x <= 5, rp = -1:-5)
print(obj2)
# above is like x[x <= 5] <- -1:-5, but using pass-by-reference

obj <- obj2 <- gen_mat()
obj

ss_set(obj, n("a"), 2L, rp = cbind(-1:-4, -5:-8))
print(obj2)
# above is like x[, "a"] <- cbind(-1:-4, -5:-8), but using pass-by-reference

obj <- obj2 <- gen_mat()
obj

ss_set(obj, n(1:3), 1:ndim(obj), tf = \(x) -x)
```

```
print(obj2)
# above is like x[1:3, 1:3] <- -1 * x[1:3, 1:3], but using pass-by-reference

obj <- obj2 <- gen_mat()
obj

i_set(obj, i = \(x) x <= 5, tf = \(x) -x)
print(obj2)
# above is like x[x <= 5] <- -1 * x[x <= 5], but using pass-by-reference

obj <- obj2 <- gen_mat()
obj

ss_set(obj, n("a"), 2L, tf = \(x) -x)
obj2
# above is like x[, "a"] <- -1 * x[, "a"], but using pass-by-reference


gen_array <- function() {
  as.mutatomic(array(1:64, c(4,4,3)))
}
obj <- obj2 <- gen_array()
obj

ss_set(obj, n(1:3, 1:2, c(1, 3)), 1:3, rp = -1:-12)
print(obj2)
# above is like x[1:3, , 1:2] <- -1:-12, but using pass-by-reference


obj <- obj2 <- gen_array()
obj
i_set(obj, i = \(x)x <= 5, rp = -1:-5)
print(obj2)
# above is like x[x <= 5] <- -1:-5, but using pass-by-reference



################################################################################

# data.table ====

obj <- data.table::data.table(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_set(
  obj, obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # WARNING: sqrt() results in `dbl`, but columns are `int`, so decimals lost
)
print(obj)

obj <- data.table::data.table(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
dt_setcoe(obj, vars = is.numeric, v = as.numeric)
str(obj)
ss2_set(obj,
  obs = ~ (a >= 2) & (c <= 17), vars = is.numeric,
  tf = sqrt # SAFE: coercion performed by dt_setcoe(); so no warnings
)
print(obj)
```

```
obj <- data.table::data.table(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
str(obj) # notice that columns "a" and "c" are INTEGER (`int`)
ss2_set(
  obj, vars = is.numeric,
  tf = sqrt # SAFE: row=NULL & obs = NULL, so coercion performed
)
str(obj)
```

---

i_wo *Methods to Return Object Without Specified Subset*

Description

S3 Methods to return an object **without** the specified subset.

Usage

```
i_wo(x, ...)

i2_wo(x, ...)

ss_wo(x, ...)

ss2_wo(x, ...)

## Default S3 method:
i_wo(x, i = NULL, ..., chkdup = getOption("squarebrackets.chkdup", FALSE))

## Default S3 method:
ss_wo(
  x,
  s = NULL,
  d = 1:ndim(x),
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
i2_wo(
  x,
  i = NULL,
  red = FALSE,
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## Default S3 method:
ss2_wo(
```

```
  x,
  s = NULL,
  d = 1:ndim(x),
  red = FALSE,
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)

## S3 method for class 'data.frame'
ss2_wo(
  x,
  s = NULL,
  d = 1:2,
  obs = NULL,
  vars = NULL,
  ...,
  chkdup = getOption("squarebrackets.chkdup", FALSE)
)
```

Arguments

x	see squarebrackets_supported_structures.
...	see squarebrackets_method_dispatch.
i, s, d, obs, vars	See squarebrackets_indx_args. An empty index selection results in nothing being removed, and the entire object is returned.
chkdup	see squarebrackets_options. for performance: set to FALSE
red	Boolean, for recursive objects only, indicating if the result should be reduced. If red = TRUE, selecting a single element will give the simplified result, like using [[]]. If red = FALSE, a list is always returned regardless of the number of elements.

Value

A copy of the sub-setted object.

Examples

```
# atomic objects ====

obj <- matrix(1:16, ncol = 4)
colnames(obj) <- c("a", "b", "c", "a")
print(obj)
ss_wo(obj, n(1:3), 1:ndim(obj))
# above is equivalent to  obj[-1:-3, -1:-3, drop = FALSE]
i_wo(obj, i = \(x) x > 5)
# above is equivalent to  obj[!obj > 5]
ss_wo(obj, n("a"), 2L)
# above is equivalent to  obj[, which(!colnames(obj) %in% "a")]
```

```
obj <- array(1:64, c(4,4,3))
print(obj)
ss_wo(obj, n(1, c(1, 3)), c(1, 3))
# above is equivalent to obj[-1, , c(-1, -3), drop = FALSE]
i_wo(obj, i = \(x)x > 5)
# above is equivalent to obj[!obj > 5]



################################################################################


# lists ====

obj <- list(a = 1:10, b = letters[1:11], c = 11:20)
print(obj)
i2_wo(obj, "a")
# above is equivalent to obj[which(!names(obj) %in% "a")]
i2_wo(obj, 1) # obj[-1]
i2_wo(obj, 1:2)
# above is equivalent to obj[seq_len(length(obj))[-1:-2]]
i2_wo(obj, is.numeric, red = TRUE)
# above is equivalent to obj[[!sapply(obj, is.numeric)]] IF this returns a single element
obj <- list(a = 1:10, b = letters[1:11], c = letters)
i2_wo(obj, is.numeric)
# above is equivalent to obj[!sapply(obj, is.numeric)] # this time singular brackets?
# for recusive indexing, see i2_rec()


obj <- rbind(
  lapply(1:4, \(x)sample(c(TRUE, FALSE, NA))),
  lapply(1:4, \(x)sample(1:10)),
  lapply(1:4, \(x)rnorm(10)),
  lapply(1:4, \(x)sample(letters))
)
colnames(obj) <- c("a", "b", "c", "a")
print(obj)
ss2_wo(obj, n(1:3), 1:ndim(obj))
# above is equivalent to obj[1:3, 1:3, drop = FALSE]
i2_wo(obj, i = is.numeric)
# above is equivalent to obj[sapply(obj, is.numeric)]
ss2_wo(obj, n(c("a", "a")), 2L)
# above is equivalent to obj[, lapply(c("a", "a"), \(i) which(colnames(obj) == i)) |> unlist()]

obj <- array(as.list(1:64), c(4,4,3))
print(obj)
ss2_wo(obj, n(1, c(1, 3)), c(1, 3))
# above is equivalent to obj[-1, , c(-1, -3), drop = FALSE]
i2_wo(obj, i = \(x)x>5)
# above is equivalent to obj[!sapply(obj, \(x) x > 5)]



################################################################################

# data.frame-like objects ====
```

```
obj <- data.frame(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
print(obj)
ss2_wo(obj, n(1:3))
# above is equivalent to obj[-1:-3, -1:-3, drop = FALSE]
ss2_wo(obj, obs = ~ (a > 5) & (c < 19), vars = is.numeric)
```

---

i_x *Methods to Extract, Exchange, or Duplicate Subsets of an Object*

Description

Methods to extract, exchange, or duplicate (i.e. repeat x times) subsets of an object.

Usage

```
i_x(x, ...)

i2_x(x, ...)

ss_x(x, ...)

ss2_x(x, ...)

## Default S3 method:
i_x(x, i = NULL, ...)

## Default S3 method:
ss_x(x, s = NULL, d = 1:ndim(x), ...)

## Default S3 method:
i2_x(x, i = NULL, red = FALSE, ...)

## Default S3 method:
ss2_x(x, s = NULL, d = 1:ndim(x), red = FALSE, ...)

## S3 method for class 'data.frame'
ss2_x(x, s = NULL, d = 1:2, obs = NULL, vars = NULL, ...)
```

Arguments

x	see squarebrackets_supported_structures.
...	see squarebrackets_method_dispatch.
i, s, d, obs, vars	See squarebrackets_indx_args. Duplicates are allowed, resulting in duplicated indices. An empty index selection results in an empty object of length 0.

red — Boolean, for recursive objects only, indicating if the result should be reduced.
If red = TRUE, selecting a single element will give the simplified result, like using [[]].
If red = FALSE, a list is always returned regardless of the number of elements.

Value

Returns a copy of the sub-setted object.

Examples

```
# atomic objects ====

obj <- matrix(1:16, ncol = 4)
colnames(obj) <- c("a", "b", "c", "a")
print(obj)
ss_x(obj, s = n(1:3), d = 1:ndim(obj))
# above is equivalent to obj[1:3, 1:3, drop = FALSE]
i_x(obj, i = \(x) x > 5)
# above is equivalent to obj[obj > 5]
ss_x(obj, s = n(c("a", "a")), d = 2L)
# above is equivalent to obj[, lapply(c("a", "a"), \(i) which(colnames(obj) == i)) |> unlist()]

obj <- array(1:64, c(4,4,3))
print(obj)
ss_x(obj, s = n(1:3, 1:2), d = c(1,3))
# above is equivalent to obj[1:3, , 1:2, drop = FALSE]
i_x(obj, i = \(x)x > 5)
# above is equivalent to obj[obj > 5]


################################################################################


# lists ====

obj <- list(a = 1:10, b = letters[1:11], c = 11:20)
print(obj)
i2_x(obj, 1) # obj[1]
i2_x(obj, 1, red = TRUE) # obj[[1]]
i2_x(obj, 1:2) # obj[1:2]
i2_x(obj, is.numeric) # obj[sapply(obj, is.numeric)]
# for recursive subsets, see i2_rec()


obj <- rbind(
  lapply(1:4, \(x)sample(c(TRUE, FALSE, NA))),
  lapply(1:4, \(x)sample(1:10)),
  lapply(1:4, \(x)rnorm(10)),
  lapply(1:4, \(x)sample(letters))
)
colnames(obj) <- c("a", "b", "c", "a")
print(obj)
ss2_x(obj, s = n(1:3), d = 1:ndim(obj))
# above is equivalent to obj[1:3, 1:3, drop = FALSE]
```

```
i2_x(obj, i = is.numeric)
# above is equivalent to obj[sapply(obj, is.numeric)]
ss2_x(obj, s = n(c("a", "a")), d = 2L)
# above is equivalent to obj[, lapply(c("a", "a"), \(i) which(colnames(obj) == i)) |> unlist()]

obj <- array(as.list(1:64), c(4,4,3))
print(obj)
ss2_x(obj, s = n(1:3, 1:2), d = c(1,3))
# above is equivalent to obj[1:3, , 1:2, drop = FALSE]
i2_x(obj, i = \(x)x > 5)
# above is equivalent to obj[sapply(obj, \(x) x > 5)]

################################################################################

# data.frame-like objects ====

obj <- data.frame(a = 1:10, b = letters[1:10], c = 11:20, d = factor(letters[1:10]))
print(obj)
ss2_x(obj, n(1:3)) # obj[1:3, 1:3, drop = FALSE]
ss2_x(obj, obs = ~ (a > 5) & (c < 19), vars = is.numeric)
```

`match_all` *Match All, Order-Sensitive and Duplicates-Sensitive*

Description

Find all indices of vector `haystack` that are equal to vector `needles`, taking into account the order of both vectors, and their duplicate values.

`match_all()` is essentially a much more efficient version of:

```
lapply(needles, \(i) which(haystack == i))
```

Like `lapply(needles, \(i) which(haystack == i))`, NAs are ignored.

`match_all()` internally calls `collapse::`fmatch and `collapse::`gsplit.
Core of the code is based on a suggestion by Sebastian Kranz (author of the 'collapse' package).

Usage

```
match_all(needles, haystack, unlist = TRUE)
```

Arguments

`needles`, `haystack`
: vectors of the same type.
`needles` cannot contain NA/NaN.
Long vectors are not supported.

`unlist` Boolean, indicating if the result should be a single unnamed integer vector (`TRUE`, default), or a named list of integer vectors (`FALSE`).

Value

An integer vector, or list of integer vectors.
If a list, each element of the list corresponds to each value of `needles`.
When `needles` and/or `haystack` is empty, or when `haystack` is fully `NA`, `match_all()` returns an empty integer vector (if `unlist = TRUE`), or an empty list (if `unlist = FALSE`).

Examples

```
n <- 200
haystack <- sample(letters, n, TRUE)
needles <- sample(letters, n/2, TRUE)
indices1 <- match_all(needles, haystack)
head(indices1)
```

---

mutatomic_class *A Class of Mutable Atomic Objects*

Description

The `mutatomic` class is a mutable version of atomic classes.
It works exactly the same in all aspects as regular atomic classes.
There is only one real difference:
Pass-by-reference functions in 'squarebrackets' only accept atomic objects when they are of class `mutatomic`, for greater safety.
In all other aspects, `mutatomic` objects are the same as R's regular atomic objects, including the behaviour of the `[<-` operator .

Exposed functions (beside the S3 methods):

- `mutatomic()`: create a `mutatomic` object from given data.
- `couldb.mutatomic()`: checks if an object could become `mutatomic`.
  An objects can become `mutatomic` if it is one of the following types:
  logical, integer, double, character, complex, raw.
  Factors can never be `mutatomic`.

Usage

```
mutatomic(data, names = NULL, dim = NULL, dimnames = NULL)

as.mutatomic(x, ...)

is.mutatomic(x)

couldb.mutatomic(x)
```

Arguments

`data`	atomic vector giving data to fill the `mutatomic` object.
`names`, `dim`, `dimnames`	see setNames and array.
`x`	an atomic object.
`...`	method dependent arguments.

Value

For `mutatomic()`, `as.mutatomic()`:
Returns a `mutatomic` object.

For `is.mutatomic()`:
Returns `TRUE` if the object is `mutatomic`, and returns `FALSE` otherwise.

For `couldb.mutatomic()`:
Returns `TRUE` if the object is one of the following types:
logical, integer, double, character, complex, raw.
Returns `FALSE` otherwise.

Warning

Always use the exported functions given by 'mutatomic' to create a `mutatomic` object, as they make necessary checks.
Circumventing these checks may break things!

Examples

```
x <- mutatomic(
  1:20, dim = c(5, 4), dimnames = list(letters[1:5], letters[1:4])
)
x

x <- matrix(1:10, ncol = 2)
x <- as.mutatomic(x)
is.mutatomic(x)
print(x)
x[, 1]
x[] <- as.double(x)
print(x)
is.mutatomic(x)
```

n *Nest*

Description

The c() function concatenates vectors or lists into a vector (if possible) or else a list.
In analogy to that function, the n() function **nests** objects into a list (not into an atomic vector, as atomic vectors cannot be nested).
It is a short-hand version of the list function.
This is handy because lists are often needed in 'squarebrackets', especially for arrays.

Usage

```
n()
```

Value

The list.

Examples

```
obj <- array(1:64, c(4,4,3))
print(obj)
ss_x(obj, n(1:3, 1:2), c(1,3))
# above is equivalent to obj[1:3, , 1:2, drop = FALSE]
```

ndim *Get Number of Dimensions*

Description

ndim(x) is short-hand for length(dim(x)).

Usage

```
ndim(x)
```

Arguments

x	the object to get the number of dimensions from.

Value

An integer, giving the number of dimensions x has.
For vectors, gives 0L.

Examples

```
x <- 1:10
ndim(x)
obj <- array(1:64, c(4,4,3))
print(obj)
ndim(obj)
```

`sb_setRename` *Safely Change the Names of a Mutable Object By Reference*

Description

Functions to rename a supported mutable object using pass-by-reference semantics:

- `sb_setFlatnames()` renames the (flat) names of a `mutatomic` object.
- `sb_setDimnames()` renames the dimension names of a `mutatomic` object.
- `sb2_setVarnames()` renames the variable names of a `data.table` object.

Usage

```
sb_setFlatnames(x, i = NULL, newnames, ...)

sb_setDimnames(x, m, newdimnames, ...)

sb2_setVarnames(x, old, new, skip_absent = FALSE, ...)
```

Arguments

`x`	a **variable** belonging to one of the supported mutable classes.
`i`	logical, numeric, character, or imaginary indices, indicating which flatnames should be changed. If `i = NULL`, the names will be completely replaced.
`newnames`	Atomic character vector giving the new names. Specifying `NULL` will remove the names.
`...`	see squarebrackets_method_dispatch.
`m`	integer vector giving the margin(s) for which to change the names (`m = 1L` for rows, `m = 2L` for columns, etc.).
`newdimnames`	a list of the same length as `m`. The first element of the list corresponds to margin `m[1]`, the second element to `m[2]`, and so on. The components of the list can be either `NULL`, or a character vector with the

	same length as the corresponding dimension. Instead of a list, simply NULL can be specified, which will remove the dimnames completely.
old	the old column names
new	the new column names, in the same order as old
skip_absent	Skip items in old that are missing (i.e. absent) in names(x). Default FALSE halts with error if any are missing.

Value

Returns: VOID. This method modifies the object by reference.
Do not use assignment like names(x) <- sb_setRename(x, ...).
Since this function returns void, you'll just get NULL.

Examples

```
# mutable atomic vector ====
x <- y <- mutatomic(1:10, names = letters[1:10])
print(x)
sb_setFlatnames(x, newnames = rev(letters[1:10]))
print(y)

x <- y <- mutatomic(1:10, names = letters[1:10])
print(x)
sb_setFlatnames(x, 1L, "XXX")
print(y)

################################################################################


# mutable atomic matrix ====
x <- mutatomic(
  1:20, dim = c(5, 4), dimnames = n(letters[1:5], letters[1:4])
)
print(x)
sb_setDimnames(
  x,
  1:2,
  lapply(dimnames(x), rev)
)
print(x)



################################################################################



# data.table ====

x <- data.table::data.table(
  a = 1:20,
  b = letters[1:20]
```

```
)
print(x)
sb2_setVarnames(x, old = names(x), new = rev(names(x)))
print(x)
```

---

slice *Efficient Sequence-based Subset Methods on (Long) Vectors*

Description

The slice_ - methods are similar to the i_/ss_ - methods, except they don't require an indexing vector, and are designed for memory efficiency.

Usage

```
slice_x(x, ...)

## Default S3 method:
slice_x(
  x,
  from = NULL,
  to = NULL,
  by = 1L,
  ...,
  use.names = TRUE,
  sticky = getOption("squarebrackets.sticky", FALSE)
)

slice_wo(x, ...)

## Default S3 method:
slice_wo(
  x,
  from = NULL,
  to = NULL,
  by = 1L,
  ...,
  use.names = TRUE,
  sticky = getOption("squarebrackets.sticky", FALSE)
)

slice_set(x, ...)

## Default S3 method:
slice_set(x, from = NULL, to = NULL, by = 1L, inv = FALSE, ..., rp, tf)
```

Arguments

x	an atomic object. For slice_set it must be a mutatomic **variable**.
...	see squarebrackets_method_dispatch.
from, to, by	see cp_seq.
use.names	Boolean, indicating if flat names should be preserved. Note that, since the slice_ methods operates on flat indices only, dimensions and dimnames are always dropped.
sticky	see squarebrackets_options.
inv	Boolean, indicating whether to invert the sequence. If TRUE, slice_set() will apply replacement/transformation on all elements of the vector, **except** for the elements of the specified sequence.
rp, tf	see squarebrackets_modify.

Value

Similar to the i_/ss_ methods.

Examples

```
x <- mutatomic(1:1e7)

# extract:
slice_x(x, 1, 10)

# reverse:
slice_x(x, -1i, 1) |> head()

# remove:
slice_wo(x, 1, -11i) # all elements except the last 10

# replace every other element:
x <- mutatomic(1:1e7)
slice_set(x, 2, -1i, 2, rp = -1)
head(x)

# replace all elements except the first element:
x <- mutatomic(1:1e7)
slice_set(x, 1, 1, inv = TRUE, rp = -1)
head(x)
```

---

slicev *Efficient Value-based Subset Methods on (Long) Vectors*

Description

The slicev_ - methods are similar to the i_/ss_ - methods, except they don't require an indexing vector, and are designed for memory efficiency.

counv(y, v, from, to) counts how often a value, or range of values, v, occurs in a vector subset y[from:to].

Usage

```
slicev_x(x, ...)

## Default S3 method:
slicev_x(
  x,
  ...,
  y = x,
  v = NULL,
  na = FALSE,
  r = TRUE,
  from = NULL,
  to = NULL,
  use.names = TRUE,
  sticky = getOption("squarebrackets.sticky", FALSE)
)

slicev_set(x, ...)

## Default S3 method:
slicev_set(
  x,
  ...,
  y = x,
  v = NULL,
  na = FALSE,
  r = TRUE,
  from = NULL,
  to = NULL,
  rp,
  tf
)

countv(y, ..., v = NULL, na = FALSE, r = TRUE, from = NULL, to = NULL)
```

Arguments

x	an atomic vector. For slicev_set() it must be a mutatomic **variable**.
...	See squarebrackets_slicev.
y, v, na, r	See squarebrackets_slicev.
from, to	see cp_seq.

use.names	Boolean, indicating if flat names should be preserved. Note that, since the slicev_ methods operates on flat indices only, dimensions and dimnames are always dropped.
sticky	see squarebrackets_options.
rp, tf	see squarebrackets_modify.

Value

Similar to the i_/ss_ methods.

For countv(): A single number, giving the number of elements matching the specified condition.

Examples

```
# basic idea ====
nms <- c(letters, LETTERS, month.abb, month.name) |> rep_len(1e6)
x <- mutatomic(1:1e6, names = nms)
head(x)

# memory efficient form of sum(x <= 10):
countv(x, v = c(-Inf, 10))

# extract all elements of x with the name "a":
slicev_x(x, y = names(x), v = "a") |> head()

# find all x smaller than or equal to 5, and replace with `-1000`:
slicev_set(x, y = x, v = c(-Inf, 5), rp = -1000L)
head(x, n = 10)


################################################################################
# Numeric range ====
#
x <- mutatomic(1:1e6)
head(x)
slicev_x(x, v= c(-Inf, 5)) # x[x <= 5]


################################################################################
# Character ====
#
x <- stringi::stri_rand_shuffle(rep("hello", 1e5))
head(x)
slicev_x(x, v = "hello") |> head() # find "hello"

# find 2 possible misspellings of "hello":
slicev_x(x, v = c("holle", "helol")) |> head()
```

`stopifnot_ma_safe2mutate` *Developer Functions for the mutatomic Class*

Description

The `stopifnot_ma_safe2mutate()` function checks if an atomic object is actually safe to mutate. The `.internal_set_ma()` function sets an object to class 'mutatomic' by reference.

Usage

```
stopifnot_ma_safe2mutate(sym, envir, .abortcall)

address(x)

.internal_set_ma(x)
```

Arguments

`sym`	the symbol of the object; i.e. `substitute(x)`.
`envir`	the environment where the object resides; i.e. `parent.frame(n = 1)`.
`.abortcall`	environment where the error message is passed to.
`x`	atomic object

Value

Nothing. Only gives an error if the object is not safe to mutate.

Examples

```
testfun1 <- function(x) {
  .internal_set_ma(x)
}


x <- 1:10
is.mutatomic(x)

testfun1(x)
is.mutatomic(x)
print(x)
```

sub2ind *Convert Subscripts to Coordinates, Coordinates to Flat Indices, and Vice-Versa*

Description

These functions convert a list of integer subscripts to an integer matrix of coordinates, an integer matrix of coordinates to an integer vector of flat indices, and vice-versa.
Inspired by the sub2ind function from 'MatLab'.

- sub2coord() converts a list of integer subscripts to an integer matrix of coordinates.
- coord2ind() converts an integer matrix of coordinates to an integer vector of flat indices.
- ind2coord() converts an integer vector of flat indices to an integer matrix of coordinates.
- coord2sub() converts an integer matrix of coordinates to a list of integer subscripts; it performs a very simple (one might even say naive) conversion.

- sub2ind() is a faster and more memory efficient version of coord2ind(sub2coord(sub, x.dims), x.dims)

All of these functions are written to be memory-efficient.
The coord2ind() is thus the opposite of arrayInd, and ind2coord is merely a convenient wrapper around arrayInd.

Note that the equivalent to the sub2ind function from 'MatLab' is actually the coord2ind() function here.

Usage

```
sub2coord(sub, x.dim)

coord2sub(coord)

coord2ind(coord, x.dim, checks = TRUE)

ind2coord(ind, x.dim)

sub2ind(sub, x.dim, checks = TRUE)
```

Arguments

sub	a list of integer subscripts. The first element of the list corresponds to the first dimension (rows), the second element to the second dimensions (columns), etc. The length of sub must be equal to the length of x.dim. One cannot give an empty subscript; instead fill in something like seq_len(dim(x)[margin]). NOTE: The coord2sub() function does not support duplicate subscripts.

x.dim	an integer vector giving the dimensions of the array in question. I.e. dim(x).
coord	an integer matrix, giving the coordinate indices (subscripts) to convert. Each row is an index, and each column is the dimension. The first columns corresponds to the first dimension, the second column to the second dimensions, etc. The number of columns of coord must be equal to the length of x.dim.
checks	Boolean, indicating if arguments checks should be performed. Defaults to TRUE. Can be set to FALSE for minor speed improvements. for performance: set to FALSE
ind	an integer vector, giving the flat position indices to convert.

Details

The base S3 vector and array classes in 'R' use the standard Linear Algebraic convention, as in academic fields like Mathematics and Statistics, in the following sense:

- vectors are **column** vectors (i.e. vertically aligned vectors);
- index counting starts at 1;
- rows are the first dimension/subscript, columns are the second dimension/subscript, etc.

Thus, the orientation of flat indices in, for example, a 4-rows-by-5-columns matrix, is as follows:

```
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
```

So in a 4 by 5 matrix, subscript `[1, 2]` corresponds to flat index 5.
Array subscripting in 'squarebrackets' also follows this standard convention.

Value

For sub2coord() and ind2coord():
Returns an integer matrix of coordinates (with properties as described in argument coord).

For coord2ind():
Returns an numeric vector of flat indices (with properties as described in argument ind).

For coord2sub():
Returns a list of integer subscripts (with properties as described in argument sub)

For sub2ind():
Returns an integer vector of flat indices(if prod(x.dim) < (2^31 - 1)), or an numeric vector of flat indices (if prod(x.dim) >= (2^31 - 1)).

Note

These functions were not specifically designed for duplicate indices per-sé.
For efficiency, they do not check for duplicate indices either.

Examples

```
x.dim <- c(10, 10, 3)
x.len <- prod(x.dim)
x <- array(1:x.len, x.dim)
sub <- list(c(4, 3), c(3, 2), c(2, 3))
coord <- sub2coord(sub, x.dim)
print(coord)
ind <- coord2ind(coord, x.dim)
print(ind)
all(x[ind] == c(x[c(4, 3), c(3, 2), c(2, 3)])) # TRUE
coord2 <- ind2coord(ind, x.dim)
print(coord)
all(coord == coord2) # TRUE
sub2 <- coord2sub(coord2)
sapply(1:3, \(i) sub2[[i]] == sub[[i]]) |> all() # TRUE
```

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