Package 'SpaDES.core'

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Type Package

Title Core Utilities for Developing and Running Spatially Explicit Discrete Event Models

Description Provides the core framework for a discrete event system to implement a complete data-to-decisions, reproducible workflow. The core components facilitate the development of modular pieces, and enable the user to include additional functionality by running user-built modules. Includes conditional scheduling, restart after interruption, packaging of reusable modules, tools for developing arbitrary automated workflows, automated interweaving of modules of different temporal resolution, and tools for visualizing and understanding the within-project dependencies.

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'code-checking.R' 'codecheck-api.R' 'codecheck-engine.R'
'codecheck-report.R' 'codecheck-rules.R' 'convertToPackage.R'
'copy.R' 'debugging.R' 'downloadData.R'
'simulation-parseModule.R' 'simulation-simInit.R' 'load.R'
'memory-leaks.R' 'memory.R' 'modActiveBinding.R'
'module-define.R' 'module-dependencies-methods.R'
'module-malformed.R' 'module-param-check.R'
'module-repository.R' 'module-template.R' 'moduleCoverage.R'
'moduleMetadata.R' 'objectSynonyms.R' 'options.R' 'paths.R'
'plotting-diagrams.R' 'plotting.R' 'progress.R'
'project-template.R' 'reexports.R' 'restart.R' 'save.R'
'saveLoadSimList.R' 'simulation-spades.R' 'spades-classes.R'
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Author Alex M Chubaty [aut] (ORCID: <https://orcid.org/0000-0001-7146-8135>),
Eliot J B McIntire [aut, cre] (ORCID:
<https://orcid.org/0000-0002-6914-8316>),
Yong Luo [ctb],
Steve Cumming [ctb],
Ceres Barros [ctb] (ORCID: <https://orcid.org/0000-0003-4036-977X>),
His Majesty the King in Right of Canada, as represented by the Minister
of Natural Resources Canada [cph]

Maintainer Eliot J B McIntire <eliot.mcintire@canada.ca>

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`SpaDES.core-package` *Categorized overview of the* `SpaDES.core` *package*

Description

`SpaDES.core` is a framework for building spatial discrete-event systems from re-usable modules. A simulation is held in a single `simList` object, modules schedule events that change the `simList`, and the events run in time order until the simulation ends.

Below is a categorized list of the functions you will use most often. Each entry is a short, plain-language description; click through for full details.

Bug reports: https://github.com/PredictiveEcology/SpaDES.core/issues

Module repository: https://github.com/PredictiveEcology/SpaDES-modules

Wiki: https://github.com/PredictiveEcology/SpaDES/wiki

Details

1 Initialize and run a simulation

`simInit()`	Set up a new simulation.
`simInit2()`	Like `simInit()`, but takes all arguments as a single list.
`spades()`	Run the simulation that `simInit()` set up.
`simInitAndSpades()`	Convenience: `simInit()` then `spades()` in one call.
`simInitAndSpades2()`	Like `simInitAndSpades()`, but takes all arguments as a single list.
`restartSpades()`	Resume a simulation after an error or interruption.
`restartOrSimInitAndSpades()`	Try to restart from a saved state; otherwise start fresh.

2 Events

Events are the building blocks of a simulation. Modules schedule events that run at a given time and may schedule further events.

`scheduleEvent()`	Schedule an event to run at a given simulation time.
`scheduleConditionalEvent()`	Schedule an event that runs when a condition becomes `TRUE`.
`conditionalEvents()`	List the conditional events currently waiting.
`doEvent()`	Internal dispatcher; usually not called directly.
`defineEvent()`	Define a new event type inside a module.

3 The `simList` object

The `simList` holds everything about a simulation: parameters, modules, the event queue, the simulation times, and all the data objects modules read and write. Its objects live in an environment, so updates happen in place rather than by copying.

simList-class	The `simList` class definition.
`envir()`	The environment that holds the simulation's objects.
`Copy()`	Make a true (deep) copy of a `simList`.

4 `simList` accessors

Functions to read and write the various parts of a `simList`. All getters have matching setters (e.g., `params(sim) <- ...`).

4.1 Parameters:

`params()`	All simulation parameters, as a nested list.
`P()`	Get a parameter for the current module without naming it.
`globals()`	Simulation-wide (global) parameters.
`paramCheckOtherMods()`	Compare a parameter's value across modules.

4.2 Paths: Where files are read from and written to.

`paths()`	All paths used by the simulation.
`getPaths()`, `setPaths()`	Get or set all paths in one call.
`cachePath()`	Where cached results are stored.
`modulePath()`	Where modules are loaded from.
`inputPath()`	Where input files are read from.
`outputPath()`	Where output files are written.
`dataPath()`	Where a module finds its `data/` folder.

`figurePath()`	Where figures are saved.
`logPath()`	Where simulation logs are written.
`scratchPath()`	Disposable working directory.
`rasterPath()`, `terraPath()`	Temporary raster directories.

4.3 Simulation times:

`time()`	The current simulation time.
`start()`, `end()`	Start and end times.
`times()`	All times (current, start, end) at once.
`timeunit()`	The time unit of the simulation (or of a module).
`timeunits()`	The time units of all modules in the simulation.
`minTimeunit()`, `maxTimeunit()`	The shortest and longest time unit in use.
`convertTimeunit()`	Convert a number between time units.
`elapsedTime()`	How much real time each module and event used.

Helpers for writing durations: `dsecond()`, `dmin()`, `dhour()`, `dday()`, `dweek()`, `dmonth()`, `dyear()`.

4.4 Event queues:

`events()`	The queue of scheduled events.
`current()`	The event being run right now.
`completed()`	Events that have already run.

4.5 Objects in the simulation:

`objs()`	All data objects in the simulation environment.
`ls()`, `objects()`	Names of those objects (base R methods).
`ls.str()`	Names plus a short summary of each object's structure.

4.6 Modules in the simulation:

`modules()`	The modules loaded in this simulation.
`depends()`	Each module's declared dependencies.
`packages()`	R packages required by the modules.

5 Building a module

5.1 Module metadata: Every module declares its name, parameters, inputs and outputs using these constructors, called inside `defineModule()`.

`defineModule()`	Top-level metadata constructor.
`defineParameter()`	Declare one parameter with a default.
`expectsInput()`	Declare one input the module reads from `sim`.

`createsOutput()`	Declare one output the module writes to `sim`.
`bindrows()`	Combine the rows above into the metadata table.

5.2 Reading module metadata back:

`moduleMetadata()`	The whole metadata block.
`moduleParams()`, `moduleInputs()`, `moduleOutputs()`	Just one slice.
`moduleObjects()`	All objects a module reads or writes.
`moduleVersion()`	The declared version.
moduleDefaults	Default values used when metadata is missing.
`parameters()`, `inputObjects()`, `outputObjects()`	Read these on a `simList`.
`citation()`, `documentation()`, `reqdPkgs()`	Other metadata accessors.

5.3 Helpers inside event functions:

`currentModule()`	The name of the running module.
`suppliedElsewhere()`	`TRUE` if another module already provides an object.
`checkObject()`	Confirm a required object exists in `sim`.
`findObjects()`	Look up objects across modules.

5.4 Authoring and packaging modules:

`newModule()`	Create a new module from a template.
`newModuleCode()`, `newModuleDocumentation()`, `newModuleTests()`	Generate individual parts of a module.
`copyModule()`	Copy a module to a new location and (optionally) re
`openModules()`	Open one or more module files in the editor.
`zipModule()`	Zip up a module for distribution.
`convertToPackage()`	Turn a module into an installable R package.
`newProject()`	Create a new project that contains modules.

6 Module dependencies and diagrams

`simInit()` works out which modules depend on which. These functions inspect that graph.

`depsEdgeList()`	Edge list of object dependencies between modules.
`depsGraph()`	The same, as an `igraph`.
`moduleDiagram()`	A simplified picture of which module feeds which.
`objectDiagram()`	A detailed picture, by individual object.
`eventDiagram()`	Gantt chart of events that ran in a completed simulation.

7 Caching

Caching makes a workflow reproducible and skips re-running steps that have not changed. Caching uses the `reproducible` package; SpaDES adds shortcuts for caching at the `spades`, module, event, and function level.

`reproducible::Cache()`	Cache any function call.
`reproducible::showCache()`	Inspect what is in the cache.
`reproducible::clearCache()`	Remove cached entries.
`reproducible::keepCache()`	Keep only the entries you name.

Inside a module's metadata you can set the parameter `.useCache` to `TRUE` (cache the whole module), a character vector (cache only those events), or use `.useCacheArgs` to pin per-event arguments to `reproducible::Cache()`. See the caching vignette: `vignette("iii-cache", package = "SpaDES.core")`.

8 Plotting

Plotting goes through `quickPlot::Plot()`, which is optimised for fast redraws within a simulation. SpaDES.core adds the `Plots()` wrapper that lets a module choose at runtime whether to render to screen, a PNG file, or no output at all.

`Plots()`	Module-friendly wrapper for any plotting function.
`anyPlotting()`	`TRUE` if the current `.plots` setting will produce any output.

9 Code checking

SpaDES.core can statically check each module's code against the metadata: every `sim$x` and parameter access is checked to be sure it matches the declared inputs, outputs, and parameters. **As of `SpaDES.core` 3.1.2.9014 these checks no longer run automatically during `simInit()`** (the default of `spades.moduleCodeChecks` is now `FALSE`); run them manually instead:

`codeCheckModule()`	Run the checks on a single module on disk (no `simInit()` needed).
`codeCheckModules()`	Vectorized form: run on one or more modules (e.g. a whole project).

Controlled by these options:

`spades.moduleCodeChecks`	Default `FALSE` (off). Set to `TRUE` (or a named list of toggles) to re-enable the in-`simInit()` chec
`spades.codeCheckEngine`	`"v1"` (default) or `"v2"` (new, structured output).

10 Persistence and recovery

`saveSimList()`	Save a `simList` to disk.
`loadSimList()`	Load one back.
`zipSimList()`, `unzipSimList()`	Save/load a `simList` together with its files.
`saveState()`	Snapshot the state during a run.
`restartR()`	Restart R (for example, to free memory) and continue.
`saveFiles()`, `loadFiles()`	Save or load files described by `outputs()` / `inputs()`.
`checksums()`	Verify (or write) checksums for a module's data files.

11 Memory monitoring

`memoryUse()`	Memory used by each event in a finished simulation.
`memoryUseThisSession()`	Memory used by the current R session.

See `vignette("iv-advanced", package = "SpaDES.core")` for how to enable the background sampler with `options(spades.memoryUseInterval = ...)`.

12 Module repository and downloads

`getModuleVersion()`	Get the latest version number on the repository.
`getSampleModules()`	Copy the bundled sample modules somewhere usable.

13 Sample modules included with the package

Three small modules in `inst/sampleModules/`, plus a module group that loads all three:

`randomLandscapes`	Generates a `SpatRaster` stack of random landscape layers.
`fireSpread`	Simulates fire ignition and spread on those layers.
`caribouMovement`	Agent-based caribou movement (correlated random walk).
`SpaDES_sampleModules`	Module group that loads all three.

Get a copy with `getSampleModules(tempdir())`.

14 Package options

Many behaviours are configurable through R options (e.g., default paths, how much output to print, code-checking, parallelism). See `spadesOptions()` for the full list with defaults and descriptions; the defaults are also returned as a named list by calling `spadesOptions()`.

Author(s)

Maintainer: Eliot J B McIntire <eliot.mcintire@canada.ca> (ORCID)

Authors:

- Eliot J B McIntire <eliot.mcintire@canada.ca> (ORCID)
- Alex M Chubaty <achubaty@for-cast.ca> (ORCID)

Other contributors:

- Yong Luo <Yong.Luo@gov.bc.ca> [contributor]
- Steve Cumming <Steve.Cumming@sbf.ulaval.ca> [contributor]
- Ceres Barros <ceres.barros@ubc.ca> (ORCID) [contributor]
- His Majesty the King in Right of Canada, as represented by the Minister of Natural Resources Canada [copyright holder]

See Also

spadesOptions()

.addChangedAttr,simList-method .addChangedAttr *for* simList *objects*

Description

This will evaluate which elements in the simList object changed following this Cached function call. It will add a named character string as an attribute attr(x, ".Cache")$changed, indicating which ones changed. When this function is subsequently called again, only these changed objects will be returned. All other simList objects will remain unchanged.

Usage

```
## S4 method for signature 'simList'
.addChangedAttr(object, preDigest, origArguments, ...)
```

Arguments

object	Any R object returned from a function
preDigest	The full, element by element hash of the input arguments to that same function, e.g., from .robustDigest
origArguments	These are the actual arguments (i.e., the values, not the names) that were the source for preDigest
...	Anything passed to methods.

Value

returns the object with attribute added

See Also

reproducible::.addChangedAttr

`.addTagsToOutput,simList-method`
`.addTagsToOutput` *for* `simList` *objects*

Description

See `reproducible::.addTagsToOutput()`.

Usage

```
## S4 method for signature 'simList'
.addTagsToOutput(object, outputObjects, FUN, preDigestByClass)
```

Arguments

`object`	Any R object returned from a function
`outputObjects`	Optional character vector indicating which objects to return. This is only relevant for list, environment (or similar) objects
`FUN`	A function
`preDigestByClass`	A list, usually from `.preDigestByClass`

Value

modified `object`, with attributes added

Author(s)

Eliot McIntire

`.cacheMessage,simList-method`
`.cacheMessage` *for* `simList` *objects*

Description

See `reproducible::.cacheMessage()`.

Usage

```
## S4 method for signature 'simList'
.cacheMessage(
  object,
  functionName,
  fromMemoise = getOption("reproducible.useMemoise", TRUE),
  verbose = getOption("reproducible.verbose")
)
```

Arguments

object	Any R object returned from a function
functionName	A character string indicating the function name
fromMemoise	Logical. If TRUE, the message will be about recovery from memoised copy
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t

See Also

reproducible::.cacheMessage

.checkCacheRepo,list-method
.checkCacheRepo *for* simList *objects*

Description

See reproducible::.checkCacheRepo().

Usage

```
## S4 method for signature 'list'
.checkCacheRepo(object, create = FALSE)
```

Arguments

object	Any R object returned from a function
create	Logical. If TRUE, then it will create the path for cache.

Value

character string representing a directory path to the cache repo

See Also

reproducible::.checkCacheRepo

`.fileExtensions` *File extensions map*

Description

How to load various types of files in R.

This function has two roles:

1. to proceed with the loading of files that are in a `simList`; or
2. as a shortcut to `simInit(inputs = filelist)`.

A `data.frame` with information on how to load various types of files in R, containing the columns:

- `exts`: the file extension;
- `fun`: the function to use for files with this file extension;
- `package`: the package from which to load `fun`.

Usage

```
.fileExtensions()

loadFiles(sim, filelist, ...)

## S4 method for signature 'simList,missing'
loadFiles(sim, filelist, ...)

## S4 method for signature 'missing,ANY'
loadFiles(sim, filelist, ...)

## S4 method for signature 'missing,missing'
loadFiles(sim, filelist, ...)

.saveFileExtensions()
```

Arguments

`sim`	`simList` object.
`filelist`	`list` or `data.frame` to call `loadFiles` directly from the `filelist` as described in Details
`...`	Additional arguments.

Value

`data.frame` of file extension, package, and function mappings

the modified `sim`, invisibly.

`data.frame`

Note

Generally not intended to be used by users.

Author(s)

Eliot McIntire and Alex Chubaty

See Also

inputs()

Examples

```
library(SpaDES.core)

# Load random maps included with package
filelist <- data.frame(
  files = dir(getMapPath(tempdir()), full.names = TRUE),
  functions = "rasterToMemory",
  package = "SpaDES.core"
)
sim1 <- loadFiles(filelist = filelist) # loads all the maps to sim1 simList

# Second, more sophisticated. All maps loaded at time = 0, and the last one is reloaded
#  at time = 10 and 20 (via "intervals").
# Also, pass the single argument as a list to all functions...
#  specifically, when add "native = TRUE" as an argument to the raster function
files <- dir(getMapPath(tempdir()), full.names = TRUE)
arguments <- I(rep(list(lyrs = 1), length(files)))
filelist <- data.frame(
   files = files,
   functions = "terra::rast",
   objectName = NA,
   arguments = arguments,
   loadTime = 0,
   intervals = c(rep(NA, length(files)-1), 10)
)

sim2 <- loadFiles(filelist = filelist) # only does the time = 0 loading; see next
end(sim2) <- 10
sim2 <- spades(sim2) # loads the object at time 10

# if we extend the end time and continue running, it will load an object scheduled
#  at time = 10, and it will also schedule a new object loading at 20 because
#  interval = 10
end(sim2) <- 20
sim2 <- spades(sim2) # loads the percentPine map 2 more times, once at 10, once at 20
```

.findSimList *Find* simList *in a nested list*

Description

This is recursive, so it will find the all simLists even if they are deeply nested.

Usage

```
.findSimList(x)
```

Arguments

x	any object, used here only when it is a list with at least one simList in it

.guessPkgFun *Guess package of a function*

Description

Guess package of a function

Usage

```
.guessPkgFun(bsf)
```

Arguments

bsf	character. A function name

Value

character. The package and function name as "pkg::bsf"

.parseElems,simList-method

.parseElems *for* simList *class objects*

Description

See quickPlot::.parseElems().

Usage

```
## S4 method for signature 'simList'
.parseElems(tmp, elems, envir)
```

Arguments

tmp	A evaluated object
elems	A character string to be parsed
envir	An environment

Value

An object, parsed from a character string and an environment.

See Also

quickPlot::.parseElems

.preDigestByClass,simList-method

Pre-digesting method for simList

Description

Takes a snapshot of simList objects.

Usage

```
## S4 method for signature 'simList'
.preDigestByClass(object)
```

Arguments

object	Any R object returned from a function

Details

See reproducible::.preDigestByClass().

Value

character vector corresponding to the names of objects stored in the .xData slot

Author(s)

Eliot McIntire

See Also

reproducible::.preDigestByClass

.prepareOutput,simList-method
.prepareOutput *for* simList *objects*

Description

See reproducible::.prepareOutput().

Usage

```
## S4 method for signature 'simList'
.prepareOutput(object, cachePath = getOption("reproducible.cachePath"), ...)
```

Arguments

object	Any R object returned from a function
cachePath	A repository used for storing cached objects. This is optional if Cache is used inside a SpaDES module.
...	Anything passed to methods.

Value

the modified object

See Also

reproducible::.prepareOutput

.quickCheck *The* SpaDES.core *variable to switch between quick and robust checking*

Description

A variable that can be use by module developers and model users to switch between a quick check of functions like downloadData, Cache. The module developer must actually use this in their code.

Usage

```
.quickCheck
```

.rndstr *Generate random strings*

Description

Generate a vector of random alphanumeric strings each of an arbitrary length.

Usage

```
.rndstr(n = 1, len = 8)

rndstr(n, len, characterFirst)

## S4 method for signature 'numeric,numeric,logical'
rndstr(n, len, characterFirst)

## S4 method for signature 'numeric,numeric,missing'
rndstr(n, len)

## S4 method for signature 'numeric,missing,logical'
rndstr(n, characterFirst)

## S4 method for signature 'missing,numeric,logical'
rndstr(len, characterFirst)

## S4 method for signature 'numeric,missing,missing'
rndstr(n)

## S4 method for signature 'missing,numeric,missing'
rndstr(len)

## S4 method for signature 'missing,missing,logical'
```

```
rndstr(characterFirst)

## S4 method for signature 'missing,missing,missing'
rndstr(n, len, characterFirst)
```

Arguments

n	Number of strings to generate (default 1). Will attempt to coerce to integer value.
len	Length of strings to generate (default 8). Will attempt to coerce to integer value.
characterFirst	Logical, if TRUE, then a letter will be the first character of the string (useful if being used for object names).

Value

Character vector of random strings.

Author(s)

Alex Chubaty and Eliot McIntire

Examples

```
set.seed(11)
rndstr()
rndstr(len = 10)
rndstr(characterFirst = FALSE)
rndstr(n = 5, len = 10)
rndstr(n = 5)
rndstr(n = 5, characterFirst = TRUE)
rndstr(len = 10, characterFirst = TRUE)
rndstr(n = 5, len = 10, characterFirst = TRUE)
```

.robustDigest,simList-method

.robustDigest *for* simList *objects*

Description

This is intended to be used within the Cache function, but can be used to evaluate what a simList would look like once it is converted to a repeatably digestible object.

Usage

```
## S4 method for signature 'simList'
.robustDigest(object, .objects, length, algo = "xxhash64", quick, classOptions)
```

Arguments

object	an object to digest.
.objects	Character vector of objects to be digested. This is only applicable if there is a list, environment (or similar) with named objects within it. Only this/these objects will be considered for caching, i.e., only use a subset of the list, environment or similar objects. In the case of nested list-type objects, this will only be applied outermost first.
length	Numeric. If the element passed to Cache is a Path class object (from e.g., asPath(filename)) or it is a Raster with file-backing, then this will be passed to digest::digest, essentially limiting the number of bytes to digest (for speed). This will only be used if quick = FALSE. Default is getOption("reproducible.length"), which is set to Inf.
algo	The digest algorithm to use. Default xxhash64 (see digest::digest() for others).
quick	Logical or character. If TRUE, no disk-based information will be assessed, i.e., only memory content. See Details section about quick in Cache().
classOptions	Optional list. This will pass into .robustDigest for specific classes. Should be options that the .robustDigest knows what to do with.

Details

See reproducible::.robustDigest(). This method strips out stuff from a simList class object that would make it otherwise not reproducibly digestible between sessions, operating systems, or machines. This will likely still not allow identical digest results across R versions.

Author(s)

Eliot McIntire

See Also

reproducible::.robustDigest()

.tagsByClass,simList-method

.tagsByClass *for* simList *objects*

Description

See reproducible::.tagsByClass(). Adds current moduleName, eventType, eventTime, and function:spades as userTags.

Usage

```
## S4 method for signature 'simList'
.tagsByClass(object)
```

Arguments

object	Any R object returned from a function

Author(s)

Eliot McIntire

See Also

reproducible::.tagsByClass

.wrap.simList *Methods for* .wrap *and* .unwrap

Description

Methods for .wrap and .unwrap

Usage

```
## S3 method for class 'simList'
.wrap(
  obj,
  cachePath = getOption("reproducible.cachePath"),
  preDigest,
  drv = getOption("reproducible.drv", NULL),
  conn = getOption("reproducible.conn", NULL),
  verbose = getOption("reproducible.verbose"),
  outputObjects = NULL,
  cacheId = NULL,
  ...
)

## S3 method for class '.simDeps'
.wrap(obj, ...)

## S3 method for class '.simDeps'
.unwrap(obj, ...)

## S3 method for class '.moduleDeps'
.wrap(obj, ...)

## S3 method for class '.moduleDeps'
.unwrap(obj, ...)

## S3 method for class 'simList'
.unwrap(
```

```
  obj,
  cachePath = getOption("reproducible.cachePath"),
  cacheId = NULL,
  drv = getOption("reproducible.drv", NULL),
  conn = getOption("reproducible.conn", NULL),
  ...
)
```

Arguments

obj	Any arbitrary R object.
cachePath	A repository used for storing cached objects. This is optional if Cache is used inside a SpaDES module.
preDigest	The list of preDigest that comes from CacheDigest of an object
drv	an object that inherits from DBIDriver, or an existing DBIConnection object (in order to clone an existing connection).
conn	A DBIConnection object, as returned by dbConnect().
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t
outputObjects	Optional character vector indicating which objects to return. This is only relevant for list, environment (or similar) objects
cacheId	An optional character vector describing the cacheIds to extract. Only entries with this/these cacheIds will be returned. If useDBI(FALSE), this will also be dramatically faster than using userTags, for a large cache.
...	Other arguments. Can be in the form of tagKey = tagValue, such as, class = "numeric" to find all entries that are numerics in the cache. Note: the special cases of cacheId and fun have their own named arguments in these functions. Also can be regexp = xx, where xx is TRUE if the user is passing a regular expression. Otherwise, userTags will need to be exact matches. Default is missing, which is the same as TRUE. If there are errors due to regular expression problem, try FALSE. For cc, it is passed to clearCache, e.g., ask, userTags. For showCache, it can also be sorted = FALSE to return the object unsorted.

Value

The same object as passed into the function, but dealt with so that it can be saved to disk.

`all.equal.simList` *All equal method for* `simList` *objects*

Description

This function removes a few attributes that are added internally by **SpaDES.core** and are not relevant to the `all.equal`. One key element removed is any time stamps, as these are guaranteed to be different. A possibly very important argument to pass to the `...` is `check.attributes = FALSE` which will allow successful comparisons of many objects that might have pointers.

Usage

```
## S3 method for class 'simList'
all.equal(target, current, ...)
```

Arguments

`target`	R object.
`current`	other R object, to be compared with `target`.
`...`	further arguments for different methods, notably the following two, for numerical comparison:

Value

See `base::all.equal()`

`anyPlotting` *Test whether there should be any plotting from* `.plots` *module parameter*

Description

This will do all the various tests needed to determine whether plotting of one sort or another will occur. Testing any of the types as listed in `Plots()` argument `types`. Only the first 3 letters of the type are required.

Usage

```
anyPlotting(.plots)
```

Arguments

`.plots`	Usually will be the `P(sim)$.plots` is used within a module.

Value

logical of length 1

append_attr *Append attributes*

Description

Ordinary base lists and vectors do not retain their attributes when subsetted or appended. This function appends items to a list while preserving the attributes of items in the list (but not of the list itself).

Usage

```
append_attr(x, y)

## S4 method for signature 'list,list'
append_attr(x, y)
```

Arguments

x, y	A list of items with optional attributes.

Details

Similar to updateList but does not require named lists.

Value

An updated list with attributes.

Author(s)

Alex Chubaty and Eliot McIntire

Examples

```
tmp1 <- list("apple", "banana")
tmp1 <- lapply(tmp1, `attributes<-`, list(type = "fruit"))
tmp2 <- list("carrot")
tmp2 <- lapply(tmp2, `attributes<-`, list(type = "vegetable"))
append_attr(tmp1, tmp2)
rm(tmp1, tmp2)
```

bindrows *Simple wrapper around* data.table::rbindlist

Description

This simply sets defaults to fill = TRUE, and use.names = TRUE.

Usage

```
bindrows(...)
```

Arguments

...	one or more data.frame, data.table, or list objects

Value

a data.table object

checkModule *Check for the existence of a remote module*

Description

Looks in the remote repo for a module named name.

Usage

```
checkModule(name, repo, token, verbose)

## S4 method for signature 'character,character'
checkModule(name, repo, token, verbose = getOption("reproducible.verbose"))

## S4 method for signature 'character,missing'
checkModule(name, token, verbose = getOption("reproducible.verbose"))
```

Arguments

name	Character string giving the module name.
repo	GitHub repository name. Default is "PredictiveEcology/SpaDES-modules", which is specified by the global option spades.moduleRepo.
token	A github repository token as from gitcreds::gitcreds_get()
verbose	Logical or Numeric, follows reproducible.verbose value by default.

Value

a character vector of module file paths (invisibly).

Author(s)

Eliot McIntire and Alex Chubaty

`checkModuleLocal` *Check for the existence of a module locally*

Description

Looks the module path for a module named `name`, and checks for existence of all essential module files listed below.

Usage

```
checkModuleLocal(name, path, version)

## S4 method for signature 'character,character,character'
checkModuleLocal(name, path, version)

## S4 method for signature 'character,ANY,ANY'
checkModuleLocal(name, path, version)
```

Arguments

`name`	Character string giving the module name.
`path`	Local path to modules directory. Default is specified by the global option `spades.modulePath`.
`version`	Character specifying the desired module version.

Details

- '`data/CHECKSUMS.txt`'
- '`name.R`'

Value

Logical indicating presence of the module (invisibly).

Author(s)

Alex Chubaty

checkModuleMetadata *Statically check a SpaDES module file for malformed metadata*

Description

Scans a module source file for common authoring mistakes that produce cryptic R parse errors or surface only deep inside `simInit()`. Returns a character vector of findings, or invisibly an empty vector if the file looks clean.

Usage

```
checkModuleMetadata(file, stopOnFirst = FALSE)
```

Arguments

`file`	Path to a module's main `.R` file.
`stopOnFirst`	Logical. If `TRUE` (default), throw an error on the first detector that fires. If `FALSE`, run every detector and return the full vector of findings.

Details

The detector set is intentionally modular: to add a new check, add an entry to the internal `.CC_MALFORMED_CHECKS` registry — each entry is a function `(input) -> NULL | character(1)`.

Value

A character vector of findings (empty if none). When `stopOnFirst = TRUE` and a problem is found, throws an error instead.

checkModulePath *Check module path*

Description

Will compare default in `spadesOptions()` (i.e., `spades.modulePath`) to `getPaths()`. Uses `"."` if `modulePath` not set (e.g., via `setPaths`). If that is the case, then use `getPaths()[["modulePath"]]`.

Usage

```
checkModulePath()
```

checkObject *Check for existence of object(s) referenced by a* objects *slot of a* simList *object*

Description

Check that a named object exists in the provide simList environment slot, and optionally has desired attributes.

Usage

```
checkObject(sim, name, object, layer, ...)

## S4 method for signature 'simList,ANY,ANY'
checkObject(sim, name, object, layer, ...)

## S4 method for signature 'simList,character,missing'
checkObject(sim, name, object, layer, ...)

## S4 method for signature 'missing,ANY,ANY'
checkObject(sim, name, object, layer, ...)
```

Arguments

sim	A simList() object.
name	A character string specifying the name of an object to be checked.
object	An object. This is mostly used internally, or with layer, because it will fail if the object does not exist.
layer	Character string, specifying a layer name in a Raster, if the name is a Raster* object.
...	Additional arguments. Not implemented.

Value

Invisibly return TRUE indicating object exists; FALSE if not.

Author(s)

Alex Chubaty and Eliot McIntire

See Also

library().

Examples

```
sim <- simInit()
sim$a <- 1
sim$b <- list(d = 1)
sim$r <- terra::rast(terra::ext(0,2,0,2), res = 1, vals = 2)
sim$s <- c(sim$r, terra::rast(terra::ext(0,2,0,2), res = 1, vals = 3))
names(sim$s) <- c("r1", "r2") # give layer names
(checkObject(sim, name = "a")) # TRUE
(checkObject(sim, name = "b", layer = "d")) # TRUE
(checkObject(sim, name = "d")) # FALSE
(checkObject(sim, name = "r")) # TRUE
(checkObject(sim, object = sim$s)) # TRUE
(checkObject(sim, object = sim$s, layer = "r1")) # TRUE
```

---

checkParams *Check use and existence of parameters passed to simulation.*

Description

Checks that all parameters passed are used in a module, and that all parameters used in a module are passed.

Usage

```
checkParams(sim, coreParams, ...)

## S4 method for signature 'simList,list'
checkParams(sim, coreParams, ...)
```

Arguments

sim	A simList simulation object.
coreParams	List of default core parameters.
...	Additional arguments. Not implemented.

Value

Invisibly returns TRUE if every parameter supplied is used by a module and every parameter a module uses was supplied; FALSE if any are unmatched; and NA if the simulation has no user modules, in which case there is nothing to check. Sensible messages are produced identifying missing parameters.

Author(s)

Alex Chubaty

checkpointFile *Simulation checkpoints*

Description

Save and reload the current state of the simulation, including the state of the random number generator, by scheduling checkpoint events.

Usage

```
checkpointFile(sim)

## S4 method for signature 'simList'
checkpointFile(sim)

checkpointFile(sim) <- value

## S4 replacement method for signature 'simList'
checkpointFile(sim) <- value

checkpointInterval(sim)

## S4 method for signature 'simList'
checkpointInterval(sim)

checkpointInterval(sim) <- value

## S4 replacement method for signature 'simList'
checkpointInterval(sim) <- value

doEvent.checkpoint(sim, eventTime, eventType, debug = FALSE)

checkpointLoad(file)

.checkpointSave(sim, file)
```

Arguments

sim	A simList simulation object.
value	The parameter value to be set (in the corresponding module and param).
eventTime	A numeric specifying the time of the next event.
eventType	A character string specifying the type of event: one of either "init", "load", or "save".
debug	Optional logical flag determines whether sim debug info will be printed (default debug = FALSE).
file	The checkpoint file.

Value

Returns the modified `simList` object.

Note

Checkpoint files are intended to be used locally, and do not invoke the simulation archiving tools to bundle and subsequently extract simulation files (e.g., file-backed rasters).

RNG save code adapted from: http://www.cookbook-r.com/Numbers/Saving_the_state_of_the_random_number_generator/ and https://stackoverflow.com/q/13997444/1380598

Author(s)

Alex Chubaty

See Also

.Random.seed.

Other functions to access elements of a 'simList' object: `.addDepends()`, `envir()`, `events()`, `globals()`, `inputs()`, `modules()`, `objs()`, `packages()`, `params()`, `paths()`, `progressInterval()`, `times()`

---

checksums *Calculate checksum for a module's data files*

Description

Verify (and optionally write) checksums for data files in a module's 'data/' subdirectory. The file 'data/CHECKSUMS.txt' contains the expected checksums for each data file. Checksums are computed using `reproducible:::.digest`, which is simply a wrapper around `digest::digest`.

Usage

```
checksums(module, path, ...)
```

Arguments

`module`	Character string giving the name of the module.
`path`	Character string giving the path to the module directory.
`...`	Passed to `reproducible::Checksums()`, notably, `write`, `quickCheck`, `checksumFile` and `files`.

Details

Modules may require data that for various reasons cannot be distributed with the module source code. In these cases, the module developer should ensure that the module downloads and extracts the data required. It is useful to not only check that the data files exist locally but that their checksums match those expected.

Note

In version 1.2.0 and earlier, two checksums per file were required because of differences in the checksum hash values on Windows and Unix-like platforms. Recent versions use a different (faster) algorithm and only require one checksum value per file. To update your 'CHECKSUMS.txt' files using the new algorithm:

1. specify your module (`moduleName <- "my_module"`);
2. use a temporary location to ensure all modules get fresh copies of the data (`tmpdir <- file.path(tempdir(), "SpaDES_modules")`);
3. download your module's data to the temp dir (`downloadData(moduleName, tmpdir)`);
4. initialize a dummy simulation to ensure any 'data prep' steps in the `.inputObjects` section are run (`simInit(modules = moduleName)`);
5. recalculate your checksums and overwrite the file (`checksums(moduleName, tmpdir, write = TRUE)`);
6. copy the new checksums file to your working module directory (the one not in the temp dir) (`file.copy(from = file.path(tmpdir, moduleName, 'data', 'CHECKSUMS.txt'), to = file.path('path/to/m moduleName, 'data', 'CHECKSUMS.txt'), overwrite = TRUE)`).

---

citation *A citation method for* SpaDES *modules*

Description

This is a wrapper around `utils::citation()` for cases with package is a `character` string. Otherwise, it takes a `simList`.

Usage

```
citation(package, lib.loc = NULL, auto = NULL, module = character())

## S4 method for signature 'simList'
citation(package, lib.loc = NULL, auto = NULL, module = character())

## S4 method for signature 'character'
citation(package, lib.loc = NULL, auto = NULL, module = character())
```

Arguments

package	For compatibility with `utils::citation()`. This can be a `simList` or a character string for a package name.
lib.loc	a character vector with path names of R libraries, or the directory containing the source for package, or `NULL`. The default value of `NULL` corresponds to all libraries currently known. If the default is used, the loaded packages are searched before the libraries.

auto	a logical indicating whether the default citation auto-generated from the package 'DESCRIPTION' metadata should be used or not, or NULL (default), indicating that a 'CITATION' file is used if it exists, or an object of class "packageDescription" with package metadata (see below).
module	Optional character string indicating which module params should come from.

Value

The citation information for a SpaDES module.

`classFilter` *Filter objects by class*

Description

Based on https://stackoverflow.com/a/5158978/1380598.

Usage

```
classFilter(x, include, exclude, envir)

## S4 method for signature 'character,character,character,environment'
classFilter(x, include, exclude, envir)

## S4 method for signature 'character,character,character,missing'
classFilter(x, include, exclude)

## S4 method for signature 'character,character,missing,environment'
classFilter(x, include, envir)

## S4 method for signature 'character,character,missing,missing'
classFilter(x, include)
```

Arguments

x	Character vector of object names to filter, possibly from ls.
include	Class(es) to include, as a character vector.
exclude	Optional class(es) to exclude, as a character vector.
envir	The environment ins which to search for objects. Default is the calling environment.

Value

Vector of object names matching the class filter.

Note

inherits() is used internally to check the object class, which can, in some cases, return results inconsistent with is. See https://stackoverflow.com/a/27923346/1380598. These (known) cases are checked manually and corrected.

Author(s)

Alex Chubaty

Examples

```
## from local (e.g., function) environment
local({
  e <- environment()
  a <- list(1:10)     # class `list`
  b <- letters        # class `character`
  d <- stats::runif(10)      # class `numeric`
  f <- sample(1L:10L) # class `numeric`, `integer`
  g <- lm( jitter(d) ~ d ) # class `lm`
  h <- glm( jitter(d) ~ d ) # class `lm`, `glm`
  classFilter(ls(), include=c("character", "list"), envir = e)
  classFilter(ls(), include = "numeric", envir = e)
  classFilter(ls(), include = "numeric", exclude = "integer", envir = e)
  classFilter(ls(), include = "lm", envir = e)
  classFilter(ls(), include = "lm", exclude = "glm", envir = e)
  rm(a, b, d, e, f, g, h)
})

## from another environment (can be omitted if .GlobalEnv)
e = new.env(parent = emptyenv())
e$a <- list(1:10)     # class `list`
e$b <- letters        # class `character`
e$d <- stats::runif(10)      # class `numeric`
e$f <- sample(1L:10L) # class `numeric`, `integer`
e$g <- lm( jitter(e$d) ~ e$d ) # class `lm`
e$h <- glm( jitter(e$d) ~ e$d ) # class `lm`, `glm`
classFilter(ls(e), include=c("character", "list"), envir = e)
classFilter(ls(e), include = "numeric", envir = e)
classFilter(ls(e), include = "numeric", exclude = "integer", envir = e)
classFilter(ls(e), include = "lm", envir = e)
classFilter(ls(e), include = "lm", exclude = "glm", envir = e)
rm(a, b, d, f, g, h, envir = e)
rm(e)
```

---

clearCache,simList-method

clearCache *for* simList *objects*

Description

This will take the `cachePath(object)` and pass

Usage

```
## S4 method for signature 'simList'
clearCache(
  x,
  userTags = character(),
  after = NULL,
  before = NULL,
  fun = NULL,
  cacheId = NULL,
  ask = getOption("reproducible.ask"),
  useCloud = FALSE,
  cloudFolderID = getOption("reproducible.cloudFolderID", NULL),
  drv = getDrv(getOption("reproducible.drv", NULL)),
  conn = getOption("reproducible.conn", NULL),
  verbose = getOption("reproducible.verbose"),
  ...
)

## S4 method for signature 'simList'
showCache(
  x,
  userTags = character(),
  after = NULL,
  before = NULL,
  fun = NULL,
  cacheId = NULL,
  drv = getDrv(getOption("reproducible.drv", NULL)),
  conn = getOption("reproducible.conn", NULL),
  verbose = getOption("reproducible.verbose"),
  ...
)

## S4 method for signature 'simList'
keepCache(
  x,
  userTags = character(),
  after = NULL,
  before = NULL,
  ask = getOption("reproducible.ask"),
  drv = getDrv(getOption("reproducible.drv", NULL)),
  conn = getOption("reproducible.conn", NULL),
  verbose = getOption("reproducible.verbose"),
  ...
)
```

Arguments

x	A simList or a directory containing a valid Cache repository. Note: For compatibility with Cache argument, cachePath can also be used instead of x, though x will take precedence.
userTags	Character vector. If used, this will be used in place of the after and before. Specifying one or more userTag here will clear all objects that match those tags. Matching is via regular expression, meaning partial matches will work unless strict beginning (^) and end ($) of string characters are used. Matching will be against any of the 3 columns returned by showCache(), i.e., artifact, tagValue or tagName. Also, if length(userTags) > 1, then matching is by and. For or matching, use | in a single character string. See examples.
after	A time (POSIX, character understandable by data.table). Objects cached after this time will be shown or deleted.
before	A time (POSIX, character understandable by data.table). Objects cached before this time will be shown or deleted.
fun	An optional character vector describing the function name to extract. Only functions with this/these functions will be returned.
cacheId	An optional character vector describing the cacheIds to extract. Only entries with this/these cacheIds will be returned. If useDBI(FALSE), this will also be dramatically faster than using userTags, for a large cache.
ask	Logical. If FALSE, then it will not ask to confirm deletions using clearCache or keepCache. Default is TRUE
useCloud	Logical. If TRUE, then every object that is deleted locally will also be deleted in the cloudFolderID, if it is non-NULL
cloudFolderID	A googledrive dribble of a folder, e.g., using drive_mkdir(). If left as NULL, the function will create a cloud folder with name from last two folder levels of the cachePath path, : paste0(basename(dirname(cachePath)), "_", basename(cachePath)). This cloudFolderID will be added to options("reproducible.cloudFolder but this will not persist across sessions. If this is a character string, it will treat this as a folder name to create or use on GoogleDrive.
drv	an object that inherits from DBIDriver, or an existing DBIConnection object (in order to clone an existing connection).
conn	A DBIConnection object, as returned by dbConnect().
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t
...	Other arguments. Can be in the form of tagKey = tagValue, such as, class = "numeric" to find all entries that are numerics in the cache. Note: the special cases of cacheId and fun have their own named arguments in these functions. Also can be regexp = xx, where xx is TRUE if the user is passing a regular expression. Otherwise, userTags will need to be exact matches. Default is missing, which is the same as TRUE. If there are errors due to regular expression problem, try FALSE. For cc, it is passed to clearCache, e.g., ask, userTags. For showCache, it can also be sorted = FALSE to return the object unsorted.

Value

A data.table object showing the subset of items in the cache, located at cachePath of the sim object, if sim is provided, or located in cachePath. For clearCache (invoked for its side effect of clearing objects matching userTags, or those between after or before), the returned data.table shows the removed items (invisibly).

---

clearCacheEventsOnly *Convenience wrapper around* clearCache *for SpaDES events*

Description

This will clear only the event- and module-level caching that is triggered using a module parameter, .useCache.

Usage

```
clearCacheEventsOnly(
  ask = TRUE,
  x = getOption("reproducible.cachePath"),
  dryRun = FALSE,
  verbose = getOption("reproducible.verbose")
)
```

Arguments

ask	Logical. If FALSE, then it will not ask to confirm deletions using clearCache or keepCache. Default is TRUE
x	A simList or a directory containing a valid Cache repository. Note: For compatibility with Cache argument, cachePath can also be used instead of x, though x will take precedence.
dryRun	logical. If FALSE, the default, then the function will deleted entries in the Cache. If TRUE, the function will identify which events and .inputObjects will be deleted, without deleting them.
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t

Value

A list of individual clearCache outputs, one for each event that was cleared.

codeCheckModule *Statically check a SpaDES module's source code (v2)*

Description

Walks the module's source via xmlparsedata, collects every reference to sim$x / sim[["x"]] / get("x", envir = envir(sim)) and to parameters (Par$x, P(sim)$x, params(sim)modx), then compares those uses to the module's defineModule() metadata. Reports any mismatches as a structured tibble of findings, optionally printed as grouped tables.

Usage

```
codeCheckModule(path, print = TRUE, enable = NULL, disable = NULL)

codeCheckModules(
  paths = dir(getOption("spades.modulePath"), full.names = TRUE),
  print = TRUE,
  enable = NULL,
  disable = NULL
)
```

Arguments

path	Path to a module directory (containing <modName>/<modName>.R, and optionally an R/ subfolder of helper scripts) or to a single .R file. If a directory, the module name is the directory's basename.
print	Logical; print the grouped report. Default TRUE.
enable, disable	Optional character vectors of rule IDs to restrict the run. See names(SpaDES.core:::.CC_RULES) for the catalogue.
paths	A character vector of module directories (or .R files), as accepted by path. Defaults to dir(getOption("spades.modulePath"), full.names = TRUE).

Details

This is the v2 implementation, selectable at simInit() time via options(spades.codeCheckEngine = "v2") (the default). The legacy v1 checker is still available via options(spades.codeCheckEngine = "v1").

Value

codeCheckModule() returns a data.frame of findings (one row per problem), invisibly; empty if the module is clean. codeCheckModules() returns, invisibly, a named list of such data.frames (named by module).

Silencing findings

Each finding in the printed report is tagged with its **rule id** in brackets, e.g. `[conflicting_fn_unqualified]`; that id (or the `· <group>` name it is printed under) is what you reference to silence it. Findings can be suppressed three ways (all honoured both here and during `simInit()`):

- **Inline `# nolint` (module developer).** Put a `# nolint` comment on the offending source line to silence every rule there, or `# nolint: <rule_id>[, <rule_id>]` to silence only specific rules (a group name such as `globals` is accepted in place of a rule id). For a metadata finding such as `in_no_default`, place it anywhere within the `expectsInput()` / `createsOutput()` / `defineParameter()` declaration, e.g. `expectsInput("cloudFolderID", "character", desc = "...") # nolint: in_no_default`. This travels with the module and documents the intent.
- `options(spades.codeChecksIgnore = ...)` **(module user).** A named list keyed by rule id (or group name) whose values are object names to ignore, e.g. `options(spades.codeChecksIgnore = list(in_no_default = c("cloudFolderID", "ecoregionRst")))`. Lets someone running another author's module quiet specific findings without editing its source.
- `options(spades.moduleCodeChecks = list(disable = ...))`. Disable whole rules by id (or restrict with `enable = ...`).

A related developer hint is `# nolint: vars a, b`: placed on a dynamic bulk-assign line whose names can't be seen statically (e.g. `list2env(someList, envir(sim))`), it asserts that objects `a`, `b` are produced there, so they aren't reported as `out_declared_unused`.

Rule catalogue

The rule ids (printed in brackets in the report), grouped by the bucket they appear under:

- **inputObjects** — `in_declared_unused` (declared input never used), `in_used_undeclared` (`sim$x` read but not in `inputObjects`), `in_no_default` (declared input has no default in `.inputObjects()`).
- **outputObjects** — `out_declared_unused` (declared output never assigned), `out_used_undeclared` (`sim$x <-` but not in `outputObjects`).
- **parameters** — `param_declared_unused`, `param_used_undeclared`, `param_used_other_module`.
- **module functions** — `must_return_sim` (a `doEvent.*` must return `sim`), `must_assign_to_sim`, `module_named_object` (`sim$<module>` collides with the module name), `clashing_module_fn`.
- **globals** — `conflicting_fn_unqualified` (a bare function name collides with a `raster::` namesake; qualify it, e.g. `raster::scale`).
- **unresolved** — `unresolved_accessor` (an accessor whose name could not be resolved statically).
- **codetools** — `codetools` (findings relayed from `codetools::checkUsageEnv`).
- **reqdPkgs** — `reqd_pkg_duplicate` (a package declared more than once in `reqdPkgs`, especially with conflicting source/version), `reqd_pkg_undeclared` (a `pkg::fn` whose `pkg` is not in `reqdPkgs`), `reqd_pkg_no_source` (best-effort, info: bare calls with no apparent source among the declared packages — only when all declared packages are installed).

codeCheckModule() checks a single module. codeCheckModules() is the vectorized form: it runs codeCheckModule() on each path in paths and returns a list of findings named by module. When paths is not supplied it defaults to every module directory under getOption("spades.modulePath"), so codeCheckModules() with no arguments checks the whole project. It replaces the manual idiom Map(codeCheckModule, dir(getOption("spades.modulePath"), full.names = TRUE)).

---

convertToPackage *Convert standard module code into an R package*

Description

EXPERIMENTAL – USE WITH CAUTION. This function attempts to convert a SpaDES module to the closest rendition of the same functionality, but in an R package. The main change is that instead of SpaDES.core parsing the functions using custom parsing tools, it will use pkgload::load_all on the package functions. These

Usage

```
convertToPackage(
  module = NULL,
  path = getOption("spades.modulePath"),
  buildDocuments = TRUE
)
```

Arguments

module	Character string of module name, without path
path	Character string of modulePath. Defaults to getOption("spades.modulePath").
buildDocuments	A logical. If TRUE, the default, then the documentation will be built, if any exists, using roxygen2::roxygenise.

Details

convertToPackage will:

1. move any functions that were defined within the main module file (moduleName.R) into the R folder, with the same name, but ending with Fns.R;
2. keep the defineModule(...) function call with all the metadata in the same file, moduleName.R, but with all other content removed, i.e., only the defineModule(...) will be here.
3. build documentation from all the **roxygen2** tags
4. places one **roxygen2** tag, @export in front of the doEvent.moduleName function, so that the function can be found by SpaDES.core
5. All other functions will be kept "private", i.e., not exported, unless the user manually adds @export, as per a normal package
6. will make a DESCRIPTION file from the SpaDES module metadata

7. will make a NAMESPACE file from the **roxygen2** tags (e.g., @export)

A user can continue to use the module code as before, i.e., by editing it and putting browser() etc. It will be parsed during simInit. Because the functions are "in a package", they are automatically namespaced with each other, so that when you want to use a function from that package, there is no need to put a prefix with the package name.

This function does not install anything (e.g., devtools::install). After running this function, simInit will automatically detect that this is now a package and will load the functions (via pkgload::load_all) from the source files. This will have the effect that it emulates the "non-package" behaviour of a SpaDES module exactly. After running this function, current tests show no impact on module behaviour, other than event-level and module-level Caching will show changes and will be rerun. Function-level Caching appears unaffected. In other words, this should cause no changes to running the module code via simInit and spades.

This function will create and fill a minimal DESCRIPTION file. This will leave the defineModule function call as the only code in the main module file. This defineModule and a doEvent.xxx are the only 2 elements that are required for an R package to be considered a SpaDES module. With these changes, the module should still function normally, but will be able to act like an R package, e.g., for writing function documentation with roxygen2, using the testthat infrastructure, etc.

This function is intended to be run once for a module that was created using the "standard" SpaDES module structure (e.g., from a newModule call). There is currently no way to "revert" the changes from R (though it can be done using version control utilities if all files are under version control, e.g., GitHub). Currently SpaDES.core identifies a module as being a package if it has a DESCRIPTION file, or if it has been installed to the .libPaths() e.g., via devtools::install or the like. So one can simply remove the package from .libPaths and delete the DESCRIPTION file and SpaDES.core will treat it as a normal module.

Value

Invoked for its side effects. There will be a new or modified DESCRIPTION file in the root directory of the module. Any functions that were in the main module script (i.e., the .R file whose filename is the name of the module and is in the root directory of the module) will be moved to individual .R files in the R folder. Any function with a dot prefix will have the dot removed in its respective filename, but the function name is unaffected.

Currently, SpaDES.core does not install the package under any circumstances. It will load it via pkgdown::load_all, and optionally (option("spades.moduleDocument" = TRUE)) build documentation via roxygen2::roxygenise within the simInit call. This means that any modifications to source code will be read in during the simInit call, as is the practice when a module is not a package.

invoked for the side effect of converting a module to a package

Reverting

Currently, this is not a reversible process. We recommend trying one module at a time, running your code. If all seems to work, then great. Commit the changes. If things don't seem to work, then revert the changes and continue on as before. Ideally, file a bug report on the SpaDES.core GitHub.com pages.

Currently

Exported functions

The only function that will be exported by default is the `doEvent.xxx`, where `xxx` is the module name. If any other module is to be exported, it must be explicitly exported with e.g., `@export`, and then building the `NAMESPACE` file, e.g., via `devtools::document(moduleRootPath)`. NOTE: as long as all the functions are being used inside each other, and they all can be traced back to a call in `doEvent.xxx`, then there is no need to export anything else.

DESCRIPTION

The `DESCRIPTION` file that is created (destroying any existing `DESCRIPTION` file) with this function will have several elements that a user may wish to change. Notably, all packages that were in `reqdPkgs` in the SpaDES module metadata will be in the `Imports` section of the `DESCRIPTION`. To accommodate the need to see these functions, a new R script, `imports.R` will be created with `@import` for each package in `reqdPkgs` of the module metadata. However, if a module already has used `@importFrom` for importing a function from a package, then the generic `@import` will be omitted for that (those) package(s). So, a user should likely follow standard R package best practices and use `@importFrom` to identify the specific functions that are required within external packages, thereby limiting function name collisions (and the warnings that come with them).

Other elements of a standard `DESCRIPTION` file that will be missing or possibly inappropriately short are `Title`, `Description`, `URL`, `BugReports`.

Installing as a package

There is no need to "install" the source code as a package because `simInit` will load it on the fly. But, there may be reasons to install it, e.g., to have access to individual functions, help manual, running tests etc. To do this, simply use the `devtools::install(pathToModuleRoot)`. Even if it is installed, `simInit` will nevertheless run `pkgload::load_all` to ensure the `spades` call will be using the current source code.

Examples

```
if (requireNamespace("ggplot2") && requireNamespace("pkgload") ) {
  tmpdir <- tempdir2()
  newModule("test", tmpdir, open = FALSE)
  convertToPackage("test", path = tmpdir)
}
```

`Copy,simList-method` *Copy for* `simList` *class objects*

Description

Because a `simList` works with an environment to hold all objects, all objects within that slot are pass-by-reference. That means it is not possible to simply copy an object with an assignment operator: the two objects will share the same objects. As one `simList` object changes so will the other. When this is not the desired behaviour, use this function.

Usage

```
## S4 method for signature 'simList'
Copy(object, objects, queues, modules, ...)
```

Arguments

`object`	An R object (likely containing environments) or an environment.
`objects`	Whether the objects contained within the `simList` environment should be copied. Default `TRUE`, which may be slow.
`queues`	Logical. Should the events queues (`events`, `current`, `completed`) be deep copied via `data.table::copy()`
`modules`	Logical. Should list of modules be copied.
`...`	Only used for custom Methods

Details

`simList` objects can contain a lot of information, much of which could be in pass-by-reference objects (e.g., `data.table` class), and objects that are file-backed, such as some `Raster*`-class objects. For all the objects that are file-backed, it is likely *very* important to give unique file-backed directories. This should be passed here, which gets passed on to the many methods of `reproducible::Copy()`.

Value

a copy of `object`

Note

uses capital C, to limit confusion with e.g., `data.table::copy()`.

Author(s)

Eliot McIntire

See Also

`reproducible::Copy()`

copyModule *Create a copy of an existing module*

Description

Create a copy of an existing module

Usage

```
copyModule(from, to, path, ...)

## S4 method for signature 'character,character,character'
copyModule(from, to, path, ...)

## S4 method for signature 'character,character,missing'
copyModule(from, to, path, ...)
```

Arguments

from	The name of the module to copy.
to	The name of the copy.
path	The path to a local module directory. Defaults to the path set by the spades.modulePath option. See setPaths().
...	Additional arguments to file.copy, e.g., overwrite = TRUE.

Value

Invisible logical indicating success (TRUE) or failure (FALSE).

Author(s)

Alex Chubaty

createsOutput *Define an output object of a module*

Description

Used to specify an output object's name, class, description and other specifications.

Usage

```
createsOutput(objectName, objectClass, desc, ...)

## S4 method for signature 'ANY,ANY,ANY'
createsOutput(objectName, objectClass, desc, ...)

## S4 method for signature 'character,character,character'
createsOutput(objectName, objectClass, desc, ...)
```

Arguments

objectName	Character string to define the output object's name.
objectClass	Character string to specify the output object's class.
desc	Text string providing a brief description of the output object. If there are extra spaces or carriage returns, these will be stripped, allowing for multi-line character strings without using paste or multiple quotes.
...	Other specifications of the output object.

Value

A data.frame suitable to be passed to outputObjects in a module's metadata.

Author(s)

Yong Luo

Examples

```
outputObjects <- bindrows(
  createsOutput(objectName = "outputObject1", objectClass = "character",
                desc = "this is for example"),
  createsOutput(objectName = "outputObject2", objectClass = "numeric",
                desc = "this is for example",
                otherInformation = "I am the second output object")
)
```

---

defineEvent *Alternative way to define events in SpaDES.core*

Description

There are two ways to define what occurs during an event: defining a function called doEvent.moduleName, where moduleName is the actual module name. This approach is the original approach used in SpaDES.core, and it must have an explicit switch statement branching on eventType. The newer approach (still experimental) uses defineEvent(). Instead of creating, doEvent.moduleName(), it creates one function for each event, each with the name doEvent.moduleName.eventName. This may be a little bit cleaner, but both with still work.

Usage

```
defineEvent(
  sim,
  eventName = "init",
  code,
  moduleName = NULL,
  envir = parent.frame()
)
```

Arguments

sim	A simList
eventName	Character string of the desired event name to define. Default is "init"
code	An expression that defines the code to execute during the event. This will be captured, and pasted into a new function (doEvent.moduleName.eventName), remaining unevaluated until that new function is called.
moduleName	Character string of the name of the module. If this function is used within a module, then it will try to find the module name.
envir	An optional environment specifying where to put the resulting function. The default is the parent.frame(), i.e. the calling environment, which for an interactive user is the global environment. Placing the function directly in the module environment (sim[[dotMods]][[moduleName]]) is not yet implemented; it requires defineEvent() to be integrated into the module parsing steps. Until then, defineEvent() is intended for standalone use.

Value

Invisibly, the simList supplied as sim. Called for its side effect of creating the event function doEvent.<moduleName>.<eventName> in envir and recording its digest in the simList.

See Also

defineModule(), simInit(), scheduleEvent()

Examples

```
sim <- simInit()

# these put the functions in the parent.frame() which is .GlobalEnv for an interactive user
defineEvent(sim, "init", moduleName = "thisTestModule", code = {
  sim <- Init(sim) # initialize
  # Now schedule some different event for "current time", i.e., will
  #   be put in the event queue to run *after* this current event is finished
  sim <- scheduleEvent(sim, time(sim), "thisTestModule", "grow")
}, envir = envir(sim))

defineEvent(sim, "grow", moduleName = "thisTestModule", code = {
  sim <- grow(sim) # grow
  # Now schedule this same event for "current time plus 1", i.e., a "loop"
```

```
  sim <- scheduleEvent(sim, time(sim) + 1, "thisTestModule", "grow") # for "time plus 1"
})

Init <- function(sim) {
  sim$messageToWorld <- "Now the sim has an object in it that can be accessed"
 sim$size <- 1 # initializes the size object --> this can be anything, Raster, list, whatever
  message(sim$messageToWorld)
  return(sim)   # returns all the things you added to sim as they are in the simList
}

grow <- function(sim) {
  sim$size <- sim$size + 1 # increments the size
  message(sim$size)
  return(sim)
}

# schedule that first "init" event
sim <- scheduleEvent(sim, 0, "thisTestModule", "init")
# Look at event queue
events(sim) # shows the "init" we just added

  # this is skipped when running in automated tests; it is fine in interactive use
  out <- spades(sim)
```

`defineModule` *Define a new module.*

Description

Specify a new module's metadata as well as object and package dependencies. Packages are loaded during this call. Any or all of these can be missing, with missing values set to defaults

Usage

```
defineModule(sim, x)

## S4 method for signature 'simList,list'
defineModule(sim, x)
```

Arguments

`sim`	A `simList` object from which to extract element(s) or in which to replace element(s).
`x`	A list with a number of named elements, referred to as the metadata. See details.

Value

Updated `simList` object.

Required metadata elements

name	Module name. Must match the filename (without the .R extension). This is currently not parsed by SpaDES
description	Brief description of the module. This is currently not parsed by SpaDES; it is for human readers only.
keywords	Author-supplied keywords. This is currently not parsed by SpaDES; it is for human readers only.
childModules	If this contains any character vector, then it will be treated as a parent module. If this is a parent module, th
authors	Module author information (as a vector of person() objects. This is currently not parsed by SpaDES; it is
version	Module version number (will be coerced to numeric_version() if a character or numeric are supplied). T
spatialExtent	The spatial extent of the module supplied via terra::ext. This is currently unimplemented. Once implem
timeframe	Vector (length 2) of POSIXt dates specifying the temporal extent of the module. Currently unimplemented.
timeunit	Time scale of the module (e.g., "day", "year"). If this is not specified, then .timeunitDefault() will be us
citation	List of character strings specifying module citation information. Alternatively, a list of filenames of .bib o
documentation	List of filenames referring to module documentation sources. This is currently not parsed by SpaDES; it is
loadOrder	Named list of length 0, 1, or 2, with names being after and before. Each element should be a character st
reqdPkgs	List of R package names required by the module. These packages will be loaded when simInit is called. R
parameters	A data.frame specifying the parameters used in the module. Usually produced by rbind-ing the outputs of
inputObjects	A data.frame specifying the data objects expected as inputs to the module, with columns objectName (cla
outputObjects	A data.frame specifying the data objects output by the module, with columns identical to those in inputO

Author(s)

Alex Chubaty

See Also

moduleDefaults(), defineEvent()

Examples

```
## a default version of the defineModule is created with a call to newModule
newModule("test", path = tempdir(), open = FALSE)

## view the resulting module file
if (interactive()) file.edit(file.path(tempdir(), "test", "test.R"))
```

---

defineParameter *Define a parameter used in a module*

Description

Used to specify a parameter's name, value, and set a default. The min and max arguments are ignored by simInit or spades; they are for human use only. To ensure that a user cannot set parameters outside of a range of values, the module developer should use assertions in their module code.

Usage

```
defineParameter(name, class, default, min, max, desc, ...)
```

Arguments

name	Character string giving the parameter name.
class	Character string giving the parameter class.
default	The default value to use when none is specified by the user. Non-standard evaluation is used for the expression.
min	With max, used to define a suitable range of values. Non-standard evaluation is used for the expression. *These are not tested by* simInit *or* spades. These are primarily for human use, i.e., to tell a module user what values the module expects.
max	With min, used to define a suitable range of values. Non-standard evaluation is used for the expression. *These are not tested by* simInit *or* spades. These are primarily for human use, i.e., to tell a module user what values the module expects.
desc	Text string providing a brief description of the parameter. If there are extra spaces or carriage returns, these will be stripped, allowing for multi-line character strings without using paste or multiple quotes.
...	A convenience that allows writing a long desc without having to use paste; any character strings after desc will be pasted together with desc.

Value

a data.frame

Note

Be sure to use the correct NA type: logical (NA), integer (NA_integer_), real (NA_real_), complex (NA_complex_), or character (NA_character_). See NA().

Author(s)

Alex Chubaty and Eliot McIntire

See Also

P(), params() for accessing these parameters in a module.

Examples

```
parameters = rbind(
  defineParameter("lambda", "numeric", 1.23, desc = "intrinsic rate of increase"),
  defineParameter("P", "numeric", 0.2, 0, 1, "probability of attack"),

  # multi-line desc without quotes on each line -- spaces and carriage returns are stripped
  defineParameter("rate", "numeric", 0.2, 0, 1,
```

```
                  "rate of arrival. This is in individuals
                  per day. This can be modified
                  by the user"),
  # multi-line desc with quotes on each line
  defineParameter("times", "numeric", 0.2, 0, 1,
                  desc = "The times during the year ",
                         "that events will occur ",
                         "with possibility of random arrival times")

)


# Create a new module, then access parameters using `P`
tmpdir <- file.path(tempdir(), "test")
checkPath(tmpdir, create = TRUE)

# creates a  new, "empty" module -- it has defaults for everything that is required
newModule("testModule", tmpdir, open = FALSE)

# Look at new module code -- see defineParameter
if (interactive()) file.edit(file.path(tmpdir, "testModule", "testModule.R"))

# initialize the simList
if (requireNamespace("ggplot2", quietly = TRUE)) {
  # Some things not necessary in this example, if not interactive (like plotting)
  opts <- if (interactive()) list() else
    options(spades.plot = NA, spades.useRequire = FALSE,
            spades.moduleCodeChecks = FALSE)
  mySim <- simInit(modules = "testModule",
                   paths = list(modulePath = tmpdir))

  # Access one of the parameters -- because this line is not inside a module
  #  function, we must specify the module name. If used within a module,
  #  we can omit the module name
  P(mySim, module = "testModule") # gets all params in a module
  P(mySim, ".useCache", "testModule") # just one param
  options(opts)
}
unlink(tmpdir, recursive = TRUE)
```

---

depsEdgeList *Build edge list for module dependency graph*

Description

Build edge list for module dependency graph

Usage

```
depsEdgeList(sim, plot, includeOutputs = FALSE)

## S4 method for signature 'simList,logical'
depsEdgeList(sim, plot, includeOutputs = FALSE)

## S4 method for signature 'simList,missing'
depsEdgeList(sim, plot)
```

Arguments

sim	A simList object.
plot	Logical indicating whether the edgelist (and subsequent graph) will be used for plotting. If TRUE, duplicated rows (i.e., multiple object dependencies between modules) are removed so that only a single arrow is drawn connecting the modules. Default is FALSE.
includeOutputs	Logical indicating whether objects that are only "outputs" will be kept and labelled as *OUTPUTS* analogous to *INPUTS*. This is relevant in the case of objectSynonyms. If an object is not used by another module then it will be removed from this depsEdgeList return; this keeps these so can be determined if they are e.g., suppliedElsewhere.

Value

A data.table whose first two columns give a list of edges and remaining columns the attributes of the dependency objects (object name, class, etc.).

Author(s)

Alex Chubaty

---

depsGraph *Build a module dependency graph*

Description

Build a module dependency graph

Usage

```
depsGraph(sim, plot)

## S4 method for signature 'simList,logical'
depsGraph(sim, plot)

## S4 method for signature 'simList,missing'
depsGraph(sim)
```

Arguments

sim	A simList object.
plot	Logical indicating whether the edgelist (and subsequent graph) will be used for plotting. If TRUE, duplicated rows (i.e., multiple object dependencies between modules) are removed so that only a single arrow is drawn connecting the modules. Default is FALSE.

Value

An igraph() object.

Author(s)

Alex Chubaty

---

dhour *SpaDES time units*

Description

SpaDES modules commonly use approximate durations that divide with no remainder among themselves. For example, models that simulate based on a "week" timestep, will likely want to fall in lock step with a second module that is a "year" timestep. Since, weeks, months, years don't really have this behaviour because of: leap years, leap seconds, not quite 52 weeks in a year, months that are of different duration, etc. We have generated a set of units that work well together that are based on the astronomical or "Julian" year. In an astronomical year, leap years are added within each year with an extra 1/4 day, (i.e., 1 year == 365.25 days); months are defined as year/12, and weeks as year/52.

Usage

```
dhour(x)

dmin(x)

dday(x)

dyears(x)

## S4 method for signature 'numeric'
dyears(x)

dmonths(x)

## S4 method for signature 'numeric'
dmonths(x)
```

```
dweeks(x)

## S4 method for signature 'numeric'
dweeks(x)

dweek(x)

dmonth(x)

dyear(x)

dsecond(x)

dNA(x)

## S4 method for signature 'ANY'
dNA(x)
```

Arguments

x	numeric. Number of the desired units

Details

When these units are not correct, a module developer can create their own time unit, and create a function to calculate the number of seconds in that unit using the "d" prefix (for duration), following the `lubridate` package standard: `ddecade <- function(x) lubridate::duration(dyear(10))`. Then the module developer can use "decade" as the module's time unit.

Value

Number of seconds within each unit

Author(s)

Eliot McIntire

---

doCallSafe *Memory safe alternative to* `do.call`

Description

`doCallSafe` is an alternative implementation for `do.call` that does not evaluate the `args` prior to running. This means that R does not become unresponsive when there are large objects in the `args`. This should be used *always* instead of `do.call`, whenever there are possibly large objects within the `args`. This is a verbatim copy from package `Gmisc` at https://search.r-project.org/CRAN/refmans/Gmisc/html/fastDoCall.html

Usage

```
doCallSafe(what, args, quote = FALSE, envir = parent.frame())
```

Arguments

what	either a function or a non-empty character string naming the function to be called.
args	a *list* of arguments to the function call. The names attribute of args gives the argument names.
quote	a logical value indicating whether to quote the arguments.
envir	an environment within which to evaluate the call. This will be most useful if what is a character string and the arguments are symbols or quoted expressions.

Value

Same as do.call, but without the memory inefficiency.

---

downloadData *Download module data*

Description

Download external data for a module if not already present in the module directory, or if there is a checksum mismatch indicating that the file is not the correct one.

Usage

```
downloadData(
  module,
  path,
  quiet,
  quickCheck = FALSE,
  overwrite = FALSE,
  files = NULL,
  checked = NULL,
  urls = NULL,
  children = NULL,
  ...
)

## S4 method for signature 'character,character,logical'
downloadData(
  module,
  path,
  quiet,
  quickCheck = FALSE,
```

```
  overwrite = FALSE,
  files = NULL,
  checked = NULL,
  urls = NULL,
  children = NULL,
  ...
)

## S4 method for signature 'character,missing,missing'
downloadData(module, quickCheck, overwrite, files, checked, urls, children)

## S4 method for signature 'character,missing,logical'
downloadData(
  module,
  quiet,
  quickCheck,
  overwrite,
  files,
  checked,
  urls,
  children
)

## S4 method for signature 'character,character,missing'
downloadData(
  module,
  path,
  quickCheck,
  overwrite,
  files,
  checked,
  urls,
  children
)
```

Arguments

module	Character string giving the name of the module.
path	Character string giving the path to the module directory.
quiet	Logical. This is passed to download.file. Default is FALSE.
quickCheck	Logical. If TRUE, then the check with local data will only use file.size instead of digest::digest. This is faster, but potentially much less robust.
overwrite	Logical. Should local data files be overwritten in case they exist? Default is FALSE.
files	A character vector of length 1 or more if only a subset of files should be checked in the 'CHECKSUMS.txt' file.

checked	The result of a previous checksums call. This should only be used when there is no possibility that the file has changed, i.e., if downloadData is called from inside another function.
urls	Character vector of urls from which to get the data. This is automatically found from module metadata when this function invoked with SpaDES.core::downloadModule(..., data = TRUE). See also reproducible::prepInputs().
children	The character vector of child modules (without path) to also run downloadData on
...	Passed to reproducible::preProcess(), e.g., purge

Details

downloadData requires a checksums file to work, as it will only download the files specified therein. Hence, module developers should make sure they have manually downloaded all the necessary data and ran checksums to build a checksums file.

There is an experimental attempt to use the **googledrive** package to download data from a shared (publicly or with individual users) file. To try this, put the Google Drive URL in sourceURL argument of expectsInputs in the module metadata, and put the filename once downloaded in the objectName argument. If using RStudio Server, you may need to use "out of band" authentication by setting options(httr_oob_default = TRUE). To avoid caching of Oauth credentials, set options(httr_oauth_cache = TRUE).

There is also an experimental option for the user to make a new 'CHECKSUMS.txt' file if there is a sourceURL but no entry for that file. This is experimental and should be used with caution.

Value

Invisibly, a list of downloaded files.

Author(s)

Alex Chubaty & Eliot McIntire

See Also

reproducible::prepInputs(), checksums(), and downloadModule() for downloading modules and building a checksums file.

Examples

```
## In metadata, each expectsInput has a sourceURL;
## downloadData will look for that and download if it defined;
## however this sample module has all NAs for sourceURL, so nothing to download.
if (FALSE) {
  modulePath <- getSampleModules(tempdir())
  downloadData("caribouMovement", path = modulePath)
}
```

`downloadModule` *Download a module from a SpaDES module GitHub repository*

Description

Download a .zip file of the module and extract (unzip) it to a user-specified location.

Usage

```
downloadModule(
  name,
  path,
  version,
  repo,
  data,
  quiet,
  quickCheck = FALSE,
  overwrite = FALSE,
  verbose = getOption("reproducible.verbose")
)

## S4 method for signature
## 'character,character,character,character,logical,logical,ANY,logical'
downloadModule(
  name,
  path,
  version,
  repo,
  data,
  quiet,
  quickCheck = FALSE,
  overwrite = FALSE,
  verbose = getOption("reproducible.verbose")
)

## S4 method for signature
## 'character,missing,missing,missing,missing,missing,ANY,ANY'
downloadModule(name, quickCheck, overwrite)

## S4 method for signature 'character,ANY,ANY,ANY,ANY,ANY,ANY,ANY'
downloadModule(name, path, version, repo, data, quiet, quickCheck, overwrite)
```

Arguments

`name`	Character string giving the module name.
`path`	Character string giving the location in which to save the downloaded module.

version	The module version to download. (If not specified, or NA, the most recent version will be retrieved.)
repo	GitHub repository name, specified as "username/repo". Default is "PredictiveEcology/SpaDES-modu which is specified by the global option spades.moduleRepo. Only master/main branches can be used at this point.
data	Logical. If TRUE, then the data that is identified in the module metadata will be downloaded, if possible. Default FALSE.
quiet	Logical. This is passed to download.file (default FALSE).
quickCheck	Logical. If TRUE, then the check with local data will only use file.size instead of digest::digest. This is faster, but potentially much less robust.
overwrite	Logical. Should local module files be overwritten in case they exist? Default FALSE.
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t

Details

Currently only works with GitHub repositories where modules are located in a modules directory in the root tree on the master branch. Module .zip files' names should contain the version number and be inside their respective module folders (see zipModule() for zip compression of modules).

Value

A list of length 2. The first element is a character vector containing a character vector of extracted files for the module. The second element is a tbl with details about the data that is relevant for the function, including whether it was downloaded or not, and whether it was renamed (because there was a local copy that had the wrong file name).

Note

downloadModule uses the GITHUB_PAT environment variable if a value is set. This alleviates 403 errors caused by too-frequent downloads. Generate a GitHub personal access token with no additional permissions at https://github.com/settings/tokens, and add this key to '.Renviron' as GITHUB_PAT=<your-github-pat-here>.

The default is to overwrite any existing files in the case of a conflict.

Author(s)

Alex Chubaty and Eliot McIntire

See Also

zipModule() for creating module .zip folders.

envir *Simulation environment*

Description

Accessor functions for the .xData slot, which is the default virtual slot for an S4 class object that inherits from an S3 object (specifically, the simList inherits from environment) in a simList object. These are included for advanced users.

Usage

```
envir(sim)

## S4 method for signature 'simList'
envir(sim)

envir(sim) <- value

## S4 replacement method for signature 'simList'
envir(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The object to be stored at the slot.

Details

Currently, only get and set methods are defined. Subset methods are not.

Value

Returns or sets the value of the slot from the simList object.

Author(s)

Alex Chubaty

See Also

SpaDES.core-package, specifically the section 1.2.8 on simList environment.

Other functions to access elements of a 'simList' object: .addDepends(), checkpointFile(), events(), globals(), inputs(), modules(), objs(), packages(), params(), paths(), progressInterval(), times()

`eventDiagram` *Simulation event diagram*

Description

Create a Gantt Chart representing the events in a completed simulation. This event diagram is constructed using the completed event list To change the number of events shown, provide an `n` argument.

Usage

```
eventDiagram(sim, n, startDate, ...)

## S4 method for signature 'simList,numeric,character'
eventDiagram(sim, n, startDate, ...)

## S4 method for signature 'simList,missing,character'
eventDiagram(sim, n, startDate, ...)

## S4 method for signature 'simList,missing,missing'
eventDiagram(sim, n, startDate, ...)
```

Arguments

`sim`	A `simList` object (typically corresponding to a completed simulation).
`n`	The number of most recently completed events to plot.
`startDate`	A character representation of date in `YYYY-MM-DD` format.
`...`	Additional arguments passed to `mermaid`. Useful for specifying `height` and `width`.

Details

Simulation time is presented on the x-axis, starting at date `startDate`. Each module appears in a colour-coded row, within which each event for that module is displayed corresponding to the sequence of events for that module. Note that only the start time of the event is meaningful is these figures: the width of the bar associated with a particular module's event DOES NOT correspond to an event's "duration".

Based on this Stack Overflow answer: https://stackoverflow.com/a/29999300/1380598.

Value

Plots an event diagram as Gantt Chart, invisibly returning a `mermaid` object.

Note

A red vertical line corresponding to the current date may appear on the figure. This is useful for Gantt Charts generally but can be considered a 'bug' here.

Author(s)

Alex Chubaty

See Also

`DiagrammeR::mermaid`.

`events` *Simulation event lists*

Description

Accessor functions for the `events` and `completed` slots of a `simList` object. These path functions will extract the values that were provided to the `simInit` function in the `path` argument.

Usage

```
events(sim, unit)

## S4 method for signature 'simList,character'
events(sim, unit)

## S4 method for signature 'simList,missing'
events(sim, unit)

events(sim) <- value

## S4 replacement method for signature 'simList'
events(sim) <- value

conditionalEvents(sim, unit)

## S4 method for signature 'simList,character'
conditionalEvents(sim, unit)

## S4 method for signature 'simList,missing'
conditionalEvents(sim, unit)

current(sim, unit)

## S4 method for signature 'simList,character'
current(sim, unit)

## S4 method for signature 'simList,missing'
current(sim, unit)

current(sim) <- value
```

```
## S4 replacement method for signature 'simList'
current(sim) <- value

completed(sim, unit, times = TRUE)

## S4 method for signature 'simList,character'
completed(sim, unit, times = TRUE)

## S4 method for signature 'simList,missing'
completed(sim, unit, times = TRUE)

completed(sim) <- value

## S4 replacement method for signature 'simList'
completed(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
unit	Character. One of the time units used in SpaDES.
value	The object to be stored at the slot.
times	Logical. Should this function report the clockTime.

Details

By default, the event lists are shown when the simList object is printed, thus most users will not require direct use of these methods.

events	Scheduled simulation events (the event queue).
completed	Completed simulation events.

Currently, only get and set methods are defined. Subset methods are not.

Value

Returns or sets the value of the slot from the simList object.

Note

Each event is represented by a data.table::data.table() row consisting of:

- eventTime: The time the event is to occur.
- moduleName: The module from which the event is taken.
- eventType: A character string for the programmer-defined event type.

See Also

SpaDES.core-package, specifically the section 1.2.6 on Simulation event queues.

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `globals()`, `inputs()`, `modules()`, `objs()`, `packages()`, `params()`, `paths()`, `progressInterval()`, `times()`

`expectsInput` *Define an input object that the module expects.*

Description

Used to specify an input object's name, class, description, source url and other specifications.

Usage

```
expectsInput(objectName, objectClass, desc, sourceURL, ...)

## S4 method for signature 'ANY,ANY,ANY,ANY'
expectsInput(objectName, objectClass, desc, sourceURL, ...)

## S4 method for signature 'character,character,character,character'
expectsInput(objectName, objectClass, desc, sourceURL, ...)

## S4 method for signature 'character,character,character,missing'
expectsInput(objectName, objectClass, desc, sourceURL, ...)
```

Arguments

`objectName`	Character string to define the input object's name.
`objectClass`	Character string to specify the input object's class.
`desc`	Text string providing a brief description of the input object. If there are extra spaces or carriage returns, these will be stripped, allowing for multi-line character strings without using `paste` or multiple quotes.
`sourceURL`	Character string to specify an URL to reach the input object, default is `NA`.
`...`	Other specifications of the input object.

Value

A `data.frame` suitable to be passed to `inputObjects` in a module's metadata.

Author(s)

Yong Luo

Examples

```
inputObjects <- bindrows(
  expectsInput(objectName = "inputObject1", objectClass = "character",
               desc = "this is for example", sourceURL = "not available"),
  expectsInput(objectName = "inputObject2", objectClass = "numeric",
               desc = "this is for example", sourceURL = "not available",
               otherInformation = "I am the second input object")
)
```

`extractURL` *Extract a url from module metadata*

Description

This will get the `sourceURL` for the object named.

Usage

```
extractURL(objectName, sim, module)

## S4 method for signature 'character,missing'
extractURL(objectName, sim, module)

## S4 method for signature 'character,simList'
extractURL(objectName, sim, module)
```

Arguments

`objectName`	A character string of the object name in the metadata.
`sim`	A `simList` object from which to extract the `sourceURL`
`module`	An optional character string of the module name whose metadata is to be used. If omitted, the function will use the `currentModule(sim)`, if defined.

Value

The url.

Author(s)

Eliot McIntire

fileName *Extract filename (without extension) of a file*

Description

Extract filename (without extension) of a file

Usage

```
fileName(x)
```

Arguments

x	List or character vector

Value

A character vector.

Author(s)

Eliot McIntire

findProjectPath *Find the project root directory*

Description

Searches upward from `path` for an RStudio project file (a `.Rproj` whose first line is `Version: `) or a git repository (a `.git` directory, or a `.git` file pointing elsewhere, as used by worktrees and submodules), falling back on `path` itself when neither is found.

Usage

```
findProjectPath(path = getwd())
```

Arguments

path	The directory to search upward from. Defaults to `getwd()`.

Details

This uses **rprojroot** when it is available. **rprojroot** is in `Suggests`, so when it is not installed this simply returns `path`, which is the same answer the fallback gives.

Value

An absolute path to the project root, or `path` if no project marker is found above it.

Examples

```
findProjectPath()                # the project the session is working in
findProjectPath(tempdir())       # no markers above tempdir(); returns it
```

`getMapPath` *Get copies of sample files for examples and tests*

Description

Get copies of sample files for examples and tests

Usage

```
getMapPath(tmpdir)

getSampleModules(tmpdir)
```

Arguments

`tmpdir`	character specifying the path to a temporary directory (e.g., `tempdir()`)

Value

character vector of filepaths to the copied files

`getModuleVersion` *Find the latest module version from a SpaDES module repository*

Description

Modified from https://stackoverflow.com/a/25485782/1380598.

Usage

```
getModuleVersion(
  name,
  repo,
  token,
  moduleFiles = NULL,
  verbose = getOption("reproducible.verbose")
)

## S4 method for signature 'character,character'
getModuleVersion(
  name,
  repo,
  token,
  moduleFiles = NULL,
  verbose = getOption("reproducible.verbose")
)

## S4 method for signature 'character,missing'
getModuleVersion(
  name,
  token,
  moduleFiles = NULL,
  verbose = getOption("reproducible.verbose")
)
```

Arguments

name	Character string giving the module name.
repo	GitHub repository name, specified as "username/repo". Default is "PredictiveEcology/SpaDES-modu which is specified by the global option spades.moduleRepo. Only master/main branches can be used at this point.
token	A github repository token as from gitcreds::gitcreds_get()
moduleFiles	Optional. List of files of the name and repo. If not supplied, this function will get that information by using checkModule.
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t

Details

getModuleVersion extracts a module's most recent version by looking at the module '.zip' files contained in the module directory. It takes the most recent version, based on the name of the zip file.

See the modules vignette for details of module directory structure (https://spades-core.predictiveecology.org/articles/ii-modules.html#module-directory-structure-modulename), and see our SpaDES-

modules repo for details of module repository structure (https://github.com/PredictiveEcology/SpaDES-modules).

Value

numeric_version

Author(s)

Alex Chubaty

See Also

zipModule() for creating module '.zip' folders.

---

globals *Get and set global simulation parameters*

Description

globals, and the alias G, accesses or sets the "globals" in the simList. This currently is not an explicit slot in the simList, but it is a .globals element in the params slot of the simList.

Usage

```
globals(sim)

## S4 method for signature 'simList'
globals(sim)

globals(sim) <- value

## S4 replacement method for signature 'simList'
globals(sim) <- value

G(sim)

## S4 method for signature 'simList'
G(sim)

G(sim) <- value

## S4 replacement method for signature 'simList'
G(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The parameter value to be set (in the corresponding module and param).

Value

For globals() and G(), a named list of the global parameters, i.e., the .globals element of the params slot. For the replacement methods globals<- and G<-, the updated simList, with any module parameters that take their value from a global re-synchronised.

See Also

SpaDES.core-package, specifically the section 1.2.1 on Simulation Parameters.

Other functions to access elements of a 'simList' object: .addDepends(), checkpointFile(), envir(), events(), inputs(), modules(), objs(), packages(), params(), paths(), progressInterval(), times()

---

initialize,simList-method

Generate a simList *object*

Description

Given the name or the definition of a class, plus optionally data to be included in the object, new returns an object from that class.

Given the name or the definition of a class, plus optionally data to be included in the object, new returns an object from that class.

Usage

```
## S4 method for signature 'simList'
initialize(.Object, ...)

## S4 method for signature 'simList_'
initialize(.Object, ...)
```

Arguments

.Object	A simList object.
...	Optional Values passed to any or all slot

`inputObjects` *Metadata accessors*

Description

These accessors extract the metadata for a module (if specified) or all modules in a `simList` if not specified.

Usage

```
inputObjects(sim, module, path)

## S4 method for signature 'simList'
inputObjects(sim, module, path)

## S4 method for signature 'missing'
inputObjects(sim, module, path)

outputObjects(sim, module, path)

## S4 method for signature 'simList'
outputObjects(sim, module, path)

## S4 method for signature 'missing'
outputObjects(sim, module, path)

outputObjectNames(sim, module)

## S4 method for signature 'simList'
outputObjectNames(sim, module)

reqdPkgs(sim, module, modulePath)

## S4 method for signature 'simList'
reqdPkgs(sim, module, modulePath)

## S4 method for signature 'missing'
reqdPkgs(sim, module, modulePath)

documentation(sim, module)

## S4 method for signature 'simList'
documentation(sim, module)

sessInfo(sim)

## S4 method for signature 'simList'
```

```
sessInfo(sim)
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
module	Character vector of module name(s)
path	The path to the module., i.e., the modulePath. Only relevant if sim not supplied.
modulePath	That path where module can be found. If set already using setPaths, it will use that. This will be ignored if sim is supplied and is required if sim not supplied

Value

The requested metadata: for a single module, the metadata itself (inputObjects() and outputObjects() give a data.frame, reqdPkgs() a character vector); for several modules, a list with one such element per module, named by module. outputObjectNames() and documentation() return a list. sessInfo() returns the sessionInfo() recorded in the simList.

Examples

```
# set modulePath
setPaths(modulePath = getSampleModules(tempdir()))
# use Require and reqdPkgs
pkgs <- reqdPkgs(module = c("caribouMovement", "randomLandscapes", "fireSpread"))
```

---

inputs *Simulation inputs*

Description

Accessor functions for the inputs slots in a simList object.

Usage

```
inputs(sim)

## S4 method for signature 'simList'
inputs(sim)

inputs(sim) <- value

## S4 replacement method for signature 'simList'
inputs(sim) <- value

inputArgs(sim)
```

```
## S4 method for signature 'simList'
inputArgs(sim)

inputArgs(sim) <- value

## S4 replacement method for signature 'simList'
inputArgs(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The object to be stored at the slot. See Details.

Details

These functions are one of three mechanisms to add the information about which input files to load in a spades call.

1. As arguments to a simInit call. Specifically, inputs or outputs. See ?simInit.
2. With the outputs(simList) function call.
3. By adding a function called .inputObjects inside a module, which will be executed during the simInit call. This last way is the most "modular" way to create default data sets for your model.

See below for more details.

Value

Returns or sets the value(s) of the input or output slots in the simList object.

inputs function or argument in simInit

inputs accepts a data.frame, with up to 7 columns. Columns are:

file	required, a character string indicating the file path. There is no default.
objectName	optional, character string indicating the name of the object that the loaded file will be assigned to in the simLis
fun	optional, a character string indicating the function to use to load that file. Defaults to the known extensions in S
package	optional character string indicating the package in which to find the fun);
loadTime	optional numeric, indicating when in simulation time the file should be loaded. The default is the highest priori
interval	optional numeric, indicating at what interval should this same exact file be reloaded from disk, e.g,. 10 would r
arguments	is a list of lists of named arguments, one list for each fun. For example, if fun="raster", arguments = list(

Currently, only file is required. All others will be filled with defaults if not specified.

See the modules vignette for more details (browseVignettes("SpaDES.core")).

`.inputObjects` function placed inside module

Any code placed inside a function called `.inputObjects` will be run during `simInit()` for the purpose of creating any objects required by this module, i.e., objects identified in the `inputObjects` element of `defineModule`. This is useful if there is something required before simulation to produce the module object dependencies, including such things as downloading default datasets, e.g., `downloadData('LCC2005', modulePath(sim))`. Nothing should be created here that does not create an named object in `inputObjects`. Any other initiation procedures should be put in the "init" `eventType` of the `doEvent` function. Note: the module developer can use `sim$.userSuppliedObjNames` inside the function to selectively skip unnecessary steps because the user has provided those `inputObjects` in the `simInit` call. e.g., the following code would look to see if the user had passed `defaultColor` into during `simInit`. If the user had done this, then this function would not override that value with 'red'. If the user has not passed in a value for `defaultColor`, then the module will get it here:

```
if (!('defaultColor' %in% sim$.userSuppliedObjNames)) { sim$defaultColor <- 'red' }
```

See Also

SpaDES.core-package, specifically the section 1.2.2 on loading and saving.

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `events()`, `globals()`, `modules()`, `objs()`, `packages()`, `params()`, `paths()`, `progressInterval()`, `times()`

Examples

```
######################
# inputs
######################

# Start with a basic empty simList
sim <- simInit()

test <- 1:10
tmpdir <- file.path(tempdir(), "inputs") |> checkPath(create = TRUE)
tmpFile <- file.path(tmpdir, "test.rds")
saveRDS(test, file = tmpFile)
inputs(sim) <- data.frame(file = tmpFile) # using only required column, "file"
inputs(sim) # see that it is not yet loaded, but when it is scheduled to be loaded
simOut <- spades(sim)
inputs(simOut) # confirm it was loaded
simOut$test

# can put data.frame for inputs directly inside simInit call
allTifs <- dir(getMapPath(tempdir()), full.names = TRUE)

# next: .objectNames are taken from the filenames (without the extension)
# This will load all 5 tifs in the SpaDES sample directory, using
#   the rast fuction in the terra package, all at time = 0
sim <- simInit(
  inputs = data.frame(
    files = allTifs,
    functions = "rast",
```

```
    package = "terra",
    loadTime = 0,
    stringsAsFactors = FALSE)
)

##############################
# A fully described inputs object, including arguments:
files <- dir(getMapPath(tempdir()), full.names = TRUE)

# arguments must be a list of lists. This may require I() to keep it as a list
#   once it gets coerced into the data.frame.
# arguments = I(rep(list(native = TRUE), length(files)))
filelist <- data.frame(
  objectName = paste0("Maps", 1:5),
  files = files,
  functions = "terra::rast",
  # arguments = arguments,
  loadTime = 0,
  intervals = c(rep(NA, length(files) - 1), 10)
)
inputs(sim) <- filelist
spades(sim)

# Example showing loading multiple objects from global environment onto the
#   same object in the simList, but at different load times
a1 <- 1
a2 <- 2
# Note arguments must be a list of NROW(inputs), with each element itself being a list,
#  which is passed to do.call(fun[x], arguments[[x]]), where x is row number, one at a time
args <- lapply(1:2, function(x) {
               list(x = paste0("a", x),
                envir = environment()) # may be necessary to specify in which envir a1, a2
                                       # are located, if not in an interactive session
               })
inputs <- data.frame(objectName = "a", loadTime = 1:2, fun = "base::get", arguments = I(args))
a <- simInit(inputs = inputs, times = list(start = 0, end = 1))
a <- spades(a)
identical(a1, a$a)

end(a) <- 3
a <- spades(a) # different object (a2) loaded onto a$a
identical(a2, a$a)

# Clean up after
unlink(tmpdir, recursive = TRUE)
```

---

inSeconds *Convert time units*

Description

Current pre-defined units are found within the `spadesTimes()` function. The user can define a new unit. The unit name can be anything, but the function definition must be of the form `"dunitName"`, e.g., `dyear` or `dfortnight`. The unit name is the part without the `d` and the function name definition includes the `d`. This new function, e.g., `dfortnight <- function(x) lubridate::duration(dday(14))` can be placed anywhere in the search path or in a module (you will need to declare `"lubridate"` in your `pkgDeps` in the metadata).

This function takes a numeric with a "unit" attribute and converts it to another numeric with a different time attribute. If the units passed to argument `units` are the same as `attr(time, "unit")`, then it simply returns input `time`.

Usage

```
inSeconds(unit, envir, skipChecks = FALSE)

convertTimeunit(time, unit, envir, skipChecks = FALSE)

.spadesTimes

spadesTimes()

checkTimeunit(unit, envir)

## S4 method for signature 'character,missing'
checkTimeunit(unit, envir)

## S4 method for signature 'character,environment'
checkTimeunit(unit, envir)
```

Arguments

`unit`	Character. One of the time units used in `SpaDES` or user defined time unit, given as the unit name only. See details.
`envir`	An environment. This is where to look up the function definition for the time unit. See details.
`skipChecks`	For speed, the internal checks for classes and missingness can be skipped. Default `FALSE`.
`time`	Numeric. With a unit attribute, indicating the time unit of the input numeric. See Details.

Details

Because of R scoping, if `envir` is a `simList` environment, then this function will search there first, then up the current `search()` path. Thus, it will find a user defined or module defined unit before a SpaDES unit. This means that a user can override the `dyear` given in SpaDES, for example, which is 365.25 days, with `dyear <- function(x) lubridate::duration(dday(365))`.

If `time` has no `unit` attribute, then it is assumed to be seconds.

Value

A numeric vector of length 1, with `unit` attribute set to "seconds".

Author(s)

Alex Chubaty & Eliot McIntire

Eliot McIntire

`loadSimList` *Load a saved* `simList` *and ancillary files*

Description

Loading a `simList` from file can be problematic as there are non-standard objects that must be rebuilt. See description in `saveSimList()` for details.

`unzipSimList` is a convenience wrapper around `unzip` and `loadSimList` where all the files are correctly identified and passed to `loadSimList(..., otherFiles = xxx)`. See zipSimList for details.

Usage

```
loadSimList(
  filename,
  projectPath = getwd(),
  tempPath = tempdir(),
  paths = NULL,
  otherFiles = "",
  verbose = getOption("reproducible.verbose")
)

unzipSimList(zipfile, load = TRUE, paths = getPaths(), ...)
```

Arguments

`filename`	Character giving the name of a saved simulation file. Currently, only file types `.qs2` or `.rds` are supported.
`projectPath`	An optional path for the project within which the `simList` exists. This is used to identify relative paths for saving and loading the `simList`.
`tempPath`	A character string specifying the new base directory for the temporary paths maintained in a `simList`.
`paths`	A list of character vectors for all the `simList` paths. When loading a `simList`, this will replace the paths of everything to these new paths. Experimental still.

otherFiles	A character vector of (absolute) file names locating each of the existing file-backed Raster* files that are the real paths for the possibly incorrect paths in Filenames(sim) if the the file being read in is from a different computer, path, or drive. This could be the output from unzipSimList (which is calls loadSimList internally, passing the unzipped filenames)
verbose	Numeric, -1 silent (where possible), 0 being very quiet, 1 showing more messaging, 2 being more messaging, etc. Default is 1. Above 3 will output much more information about the internals of Caching, which may help diagnose Caching challenges. Can set globally with an option, e.g., options('reproducible.verbose' = 0) to reduce t
zipfile	Filename of a zipped simList
load	Logical. If TRUE, the default, then the simList will also be loaded into R.
...	passed to unzip

Details

If cache is used, it is likely that it should be trimmed before zipping, to include only cache elements that are relevant.

Value

For loadSimList(), a simList object. For unzipSimList(), either a character vector of file names unzipped (if load = FALSE), or a simList object.

See Also

saveSimList(), zipSimList()

---

makeMemoisable.simList

Make simList *correctly work with* memoise

Description

Because of the environment slot, simList objects don't correctly memoise a simList. This method for simList converts the object to a simList_ first.

Usage

```
## S3 method for class 'simList'
makeMemoisable(x)

## S3 method for class 'simList_'
unmakeMemoisable(x)
```

Arguments

x	An object to make memoisable. See individual methods in other packages.

Value

A simList_ object or a simList, in the case of unmakeMemoisable.

See Also

reproducible::makeMemoisable()

---

maxTimeunit *Determine the largest timestep unit in a simulation*

Description

Determine the largest timestep unit in a simulation

Usage

```
maxTimeunit(sim)

## S4 method for signature 'simList'
maxTimeunit(sim)
```

Arguments

sim	A simList simulation object.

Value

The timeunit as a character string. This defaults to NA if none of the modules has explicit units.

Author(s)

Eliot McIntire and Alex Chubaty

---

memoryUseThisSession *Estimate memory used with* system("ps")

Description

This will give a slightly different estimate than pryr::mem_used, which uses gc() internally. The purpose of this function is to allow continuous monitoring, external to the R session. Normally, this is run in a different session.

This will only work if the user has specified before running the spades call, set the interval, in seconds, that ps is run. E.g., options("spades.memoryUseInterval" = 0.5), will assess memory use every 0.5 seconds. The default is 0, meaning no interval, "off".

Usage

```
memoryUseThisSession(thisPid)

memoryUse(sim, max = TRUE)
```

Arguments

thisPid	Numeric or integer, the PID of the process. If omitted, it will be found with Sys.getpid().
sim	A completed simList
max	Logical. If TRUE, then it the return value will be summarized by module/event, showing the maximum memory used. If FALSE, then the raw memory used during each event will be shown.

Value

estimated memory use in MiB

data.table summarizing the estimated memory use (in MiB) for each event type, for each module, during the simulation.

Note

The suggested future and future.callr packages must be available.

See Also

The vignette("iv-modules")

---

minTimeunit *Determine the smallest timeunit in a simulation*

Description

When modules have different timeunit, SpaDES automatically takes the smallest (e.g., "second") as the unit for a simulation.

Usage

```
minTimeunit(sim)

## S4 method for signature 'simList'
minTimeunit(sim)

## S4 method for signature 'list'
minTimeunit(sim)
```

Arguments

sim	A simList simulation object.

Value

The timeunit as a character string. This defaults to "second" if none of the modules has explicit units.

Author(s)

Eliot McIntire

---

moduleCodeFiles *Extract the full file paths for R source code*

Description

This can be used e.g., for Caching, to identify which files have changed.

Usage

```
moduleCodeFiles(paths, modules)
```

Arguments

paths	An optional named list with up to 4 named elements, modulePath, inputPath, outputPath, and cachePath. See details. NOTE: Experimental feature now allows for multiple modulePaths to be specified in a character vector. The modules will be searched for sequentially in the first modulePath, then if it doesn't find it, in the second etc.
modules	A named list of character strings specifying the names of modules to be loaded for the simulation. Note: the module name should correspond to the R source file from which the module is loaded. Example: a module named "caribou" will be sourced form the file 'caribou.R', located at the specified modulePath(simList) (see below).

Value

character vector of file paths.

`moduleCoverage` *Calculate module coverage of unit tests*

Description

Calculate the test coverage by unit tests for the module and its functions.

Usage

```
moduleCoverage(mod, modulePath = "..")
```

Arguments

`mod`	Character string. The module's name. Default is `basename(getwd())`
`modulePath`	Character string. The path to the module directory (default is "..", i.e., one level up from working directory).

Value

Return a list of two coverage objects and two data.table objects. The two coverage objects are named `moduleCoverage` and `functionCoverage`. The `moduleCoverage` object contains the percent value of unit test coverage for the module. The `functionCoverage` object contains percentage values for unit test coverage for each function defined in the module. Please use `covr::report()` to view the coverage information. Two data.tables give the information of all the tested and untested functions in the module.

Note

When running this function, the test files must be strictly placed in the '`tests/testthat/`' directory under module path. To automatically generate this folder, please set `unitTests = TRUE` when creating a new module using `newModule()`. To accurately test your module, the test filename must follow the format `test-functionName.R`.

Author(s)

Yong Luo

See Also

`newModule()`.

moduleDefaults *Defaults values used in* defineModule

Description

Where individual elements are missing in defineModule, these defaults will be used.

Usage

```
moduleDefaults
```

Value

named list of default module metadata

moduleDiagram *Simulation module dependency diagram*

Description

Create a network diagram illustrating the simplified module dependencies of a simulation. Offers a less detailed view of specific objects than does plotting the depsEdgeList directly with objectDiagram().

Usage

```
moduleDiagram(sim, type, showParents = TRUE, ...)

## S4 method for signature 'simList,character,logical'
moduleDiagram(sim, type = "plot", showParents = TRUE, ...)

## S4 method for signature 'simList,ANY,ANY'
moduleDiagram(sim, type, showParents = TRUE, ...)
```

Arguments

sim	A simList object (typically corresponding to a completed simulation).
type	Character string, either "rgl" for igraph::rglplot or "tk" for igraph::tkplot, "Plot" to use quickPlot::Plot() or "plot" to use base::plot(), the default.
showParents	Logical. If TRUE, then any children that are grouped into parent modules will be grouped together by coloured blobs. Internally, this is calling moduleGraph(). Default FALSE.
...	Additional arguments passed to plotting function specified by type.

Value

invoked for its side effect of plotting the module dependency diagram.

Author(s)

Alex Chubaty

See Also

igraph::igraph, `moduleGraph()` for a version that accounts for parent and children module structure.

Examples

```
if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
library(igraph)
times <- list(start = 0, end = 6, "month")
parameters <- list(
  .globals = list(stackName = "landscape"),
  caribouMovement = list(
    .saveObjects = "caribou",
    .saveInitialTime = 1, .saveInterval = 1
  ),
  randomLandscapes = list(.plotInitialTime = NA, nx = 20, ny = 20))

modules <- list("randomLandscapes", "caribouMovement")
paths <- list(
  modulePath = getSampleModules(tempdir())
)

# Set some options so example runs faster
opts <- options(spades.moduleCodeChecks = FALSE, spades.loadReqdPkgs = FALSE)
sim <- simInit(times = times, params = parameters, modules = modules,
               paths = paths)
options(opts)
moduleDiagram(sim)
# Can also use default base::plot
modDia <- depsGraph(sim, plot = TRUE)
# See ?plot.igraph
plot(modDia, layout = layout_as_star)

# Or for more control - here, change the label "_INPUT_" to "DATA"
edgeList <- depsEdgeList(sim)
edgeList <- edgeList[, list(from, to)]
edgeList[from == "_INPUT_", from := "Data"]
edgeList[to == "_INPUT_", to := "Data"]
edgeList <- unique(edgeList)
ig <- graph_from_data_frame(edgeList[, list(from, to)])
plot(ig)
}
```

moduleGraph *Build a module dependency graph*

Description

This is still experimental, but this will show the hierarchical structure of parent and children modules and return a list with an igraph object and an igraph communities object, showing the groups. Currently only tested with relatively simple structures.

Usage

```
moduleGraph(sim, plot, ...)

## S4 method for signature 'simList,logical'
moduleGraph(sim, plot, ...)

## S4 method for signature 'simList,missing'
moduleGraph(sim, plot, ...)
```

Arguments

sim	A simList object.
plot	Logical indicating whether the edgelist (and subsequent graph) will be used for plotting. If TRUE, duplicated rows (i.e., multiple object dependencies between modules) are removed so that only a single arrow is drawn connecting the modules. Default is FALSE.
...	Arguments passed to Plot

Value

A list with 2 elements, an igraph::igraph object and an igraph communities object.

Author(s)

Eliot McIntire

See Also

moduleDiagram()

moduleMetadata *Parse and extract module metadata*

Description

Parse and extract module metadata

Usage

```
moduleMetadata(
  sim,
  module,
  path = getOption("spades.modulePath", NULL),
 defineModuleListItems = c("name", "description", "keywords", "childModules", "authors",
  "version", "spatialExtent", "timeframe", "timeunit", "citation", "documentation",
   "reqdPkgs", "parameters", "inputObjects", "outputObjects")
)

## S4 method for signature 'missing,character,character'
moduleMetadata(module, path, defineModuleListItems)

## S4 method for signature 'missing,character,missing'
moduleMetadata(module, defineModuleListItems)

## S4 method for signature 'ANY,ANY,ANY'
moduleMetadata(
  sim,
  module,
  path = getOption("spades.modulePath", NULL),
 defineModuleListItems = c("name", "description", "keywords", "childModules", "authors",
  "version", "spatialExtent", "timeframe", "timeunit", "citation", "documentation",
   "reqdPkgs", "parameters", "inputObjects", "outputObjects")
)
```

Arguments

sim	A simList simulation object, generally produced by simInit.
module	Character string. Your module's name.
path	Character string specifying the file path to modules directory. Default is to use the spades.modulePath option.
defineModuleListItems	A vector of metadata entries to return values about.

Value

A list of module metadata, matching the structure in defineModule().

Author(s)

Alex Chubaty

See Also

defineModule()

Examples

```
## turn off code checking -- don't need it here
opts <- options("spades.moduleCodeChecks" = FALSE,
                "spades.useRequire" = FALSE)

path <- getSampleModules(tempdir())
sampleModules <- dir(path)
x <- moduleMetadata(sampleModules[3], path = path)

## using simList
if (require("SpaDES.tools", quietly = TRUE)) {
   mySim <- simInit(
      times = list(start = 2000.0, end = 2001.0, timeunit = "year"),
      params = list(
        .globals = list(stackName = "landscape")
      ),
      modules = list("caribouMovement"),
      paths = list(modulePath = path)
   )
   moduleMetadata(sim = mySim)
}

# turn code checking back on -- don't need it here
options(opts)
```

---

moduleParams *Extract a module's parameters, inputs, or outputs*

Description

These are more or less wrappers around `moduleMetadata`, with the exception that extraneous spaces and End-Of-Line characters will be removed from the `desc` arguments in `defineParameters`, `defineInputs`, and `defineOutputs`

Usage

```
moduleParams(module, path)

## S4 method for signature 'character,character'
moduleParams(module, path)
```

```
moduleInputs(module, path)

## S4 method for signature 'character,character'
moduleInputs(module, path)

moduleOutputs(module, path)

## S4 method for signature 'character,character'
moduleOutputs(module, path)
```

Arguments

module	Character string. Your module's name.
path	Character string specifying the file path to modules directory. Default is to use the spades.modulePath option.

Value

data.frame

Author(s)

Alex Chubaty

See Also

moduleMetadata()

Examples

```
## easily include these tables in Rmd files using knitr
path <- getSampleModules(tempdir())
sampleModules <- dir(path)

p <- moduleParams(sampleModules[3], path = path)
i <- moduleInputs(sampleModules[3], path = path)
o <- moduleOutputs(sampleModules[3], path = path)

knitr::kable(p)
knitr::kable(i)
knitr::kable(o)
```

modules *Simulation modules and dependencies*

Description

Accessor functions for the depends and modules slots in a simList object. These are included for advanced users.

depends()	List of simulation module dependencies. (advanced)
modules()	List of simulation modules to be loaded. (advanced)
inputs()	List of loaded objects used in simulation. (advanced)

Usage

```
modules(sim, hidden = FALSE)

## S4 method for signature 'simList'
modules(sim, hidden = FALSE)

modules(sim) <- value

## S4 replacement method for signature 'simList'
modules(sim) <- value

depends(sim)

## S4 method for signature 'simList'
depends(sim)

depends(sim) <- value

## S4 replacement method for signature 'simList'
depends(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
hidden	Logical. If TRUE, show the default core modules.
value	The object to be stored at the slot.

Details

Currently, only get and set methods are defined. Subset methods are not.

Value

Returns or sets the value of the slot from the `simList` object.

Author(s)

Alex Chubaty

See Also

SpaDES.core-package, specifically the section 1.2.7 on Modules and dependencies.

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `events()`, `globals()`, `inputs()`, `objs()`, `packages()`, `params()`, `paths()`, `progressInterval()`, `times()`

---

moduleVersion *Parse and extract a module's version*

Description

Parse and extract a module's version

Usage

```
moduleVersion(module, path, sim, envir = NULL)

## S4 method for signature 'character,character,missing'
moduleVersion(module, path, envir)

## S4 method for signature 'character,missing,missing'
moduleVersion(module, envir)

## S4 method for signature 'character,missing,simList'
moduleVersion(module, sim, envir)
```

Arguments

`module`	Character string. Your module's name.
`path`	Character string specifying the file path to modules directory. Default is to use the `spades.modulePath` option.
`sim`	A `simList` simulation object, generally produced by `simInit`.
`envir`	Optional environment in which to store parsed code. This may be useful if the same file is being parsed multiple times. This function will check in that environment for the parsed file before parsing again. If the `envir` is transient, then this will have no effect.

Value

numeric_version indicating the module's version.

Author(s)

Alex Chubaty

See Also

moduleMetadata()

Examples

```
# using filepath
path <- getSampleModules(tempdir())
moduleVersion("caribouMovement", path)

# using simList
options("spades.useRequire" = FALSE)
if (require("SpaDES.tools", quietly = TRUE)) {
   mySim <- simInit(
      times = list(start = 2000.0, end = 2002.0, timeunit = "year"),
      params = list(
        .globals = list(stackName = "landscape", burnStats = "nPixelsBurned")
      ),
      modules = list("caribouMovement"),
      paths = list(modulePath = path)
   )
   moduleVersion("caribouMovement", sim = mySim)
}
```

---

newModule *Create new module from template*

Description

Generate a skeleton for a new SpaDES module, a template for a documentation file, a citation file, a license file, a 'README.md' file, and a folder that contains unit tests information. newModule is largely a wrapper around newModuleCode and newModuleDocumentation. newModuleCode will not generate the module code. newModuleDocumentation will create the other files.

Usage

```
newModule(name, path, ..., events = NULL, envir = parent.frame())

## S4 method for signature 'character,character'
newModule(name, path, ..., events = NULL, envir = parent.frame())
```

```
## S4 method for signature 'character,missing'
newModule(name, path, ..., events = NULL, envir = parent.frame())

newModuleCode(name, path, ..., events)

## S4 method for signature 'character,character'
newModuleCode(name, path, ..., events)

newModuleDocumentation(name, path, ...)

## S4 method for signature 'character,character'
newModuleDocumentation(name, path, ...)

## S4 method for signature 'character,missing'
newModuleDocumentation(name, path, ...)
```

Arguments

name	Character string specifying the name of the new module.
path	Character string. Subdirectory in which to place the new module code file. The default is the current working directory.
...	Additional arguments. Currently, these can be either named function definitions (which will be added to the simList) or one or more of the following:

children Required when type = "parent". A character vector specifying the names of child modules.

open Logical. Should the new module file be opened after creation? Default TRUE.

type Character string specifying one of "child" (default), or "parent".

For newModule can also be:

unitTests Logical. Should the new module include unit test files? Default TRUE. Unit testing relies on the **testthat** package.

useGitHub Logical. Is module development happening on GitHub? Default TRUE.

events	A list of named expressions, each of which is surrounded by { }. A user can specify events here, instead of accepting the default doEvent function that comes with the module template. If this is specified, all events must be specified, i.e., it will not inherit partially from the template doEvent.<moduleName>. See example.
envir	An environment where objects being passed to newModule can be found. Default parent.frame(), which should be fine for most cases.

Details

All files will be created within a subdirectory named `name` within the `path`:

```
<path>/
  |_ <name>/
  |_ R/               # contains additional module R scripts
  |_ data/            # directory for all included data
    |_ CHECKSUMS.txt  # contains checksums for data files
  |_ tests/           # contains unit tests for module code
  |_ citation.bib     # bibtex citation for the module
  |_ LICENSE          # describes module's legal usage
  |_ README.md        # provide overview of key aspects
  |_ <name>.R         # module code file (incl. metadata)
  |_ <name>.Rmd       # documentation, usage info, etc.
```

Value

NULL (invisibly). The new module file is created at '`path/name.R`', as well as ancillary files for documentation, citation, '`LICENSE`', '`README`', and '`tests`' directory.

`newModuleCode` is invoked for its side effect of creating new module code files.

`newModuleDocumentation` is invoked for its side effect of creating new module documentation files.

Note

On Windows there is currently a bug in RStudio that prevents the editor from opening when `file.edit` is called. Similarly, in RStudio on macOS, there is an issue opening files where they are opened in an overlaid window rather than a new tab. `file.edit` does work if the user types it at the command prompt. A message with the correct lines to copy and paste is provided.

Author(s)

Alex Chubaty and Eliot McIntire

Eliot McIntire and Alex Chubaty

See Also

Other module creation helpers: `newModuleTests()`

Examples

```
tmpdir <- tempdir2("exampleNewModule")
## create a "myModule" module in the "modules" subdirectory.
newModule("myModule", tmpdir)

## create a new parent module in the "modules" subdirectory.
newModule("myParentModule", tmpdir, type = "parent", children = c("child1", "child2"))
unlink(tmpdir, recursive = TRUE)
```

```
if (requireNamespace("ggplot2")) {
  # We can also specify events and functions in `newModule`; it will still get all
  #   functions that are not specified from the module template (e.g., plotFun below)
  nm <- "test"
  modulePath <- Require::tempdir2()
  newModule(nm, path = modulePath, open = FALSE,
            events = list(
              init = {
                  sim <- Init(sim)                          # finds definition below
                  sim <- scheduleEvent(sim, start(sim) + 1,
                                       eventType = "plot")
              },
              plot = {
                 plotFun(sim)                               # finds the templated plotFun
                  sim <- scheduleEvent(sim, time(sim) + 1,
                                       eventType = "plot")
              }
              ,
            ),
            Init = function(sim) { # replaces Init definition from template
              sim$a <- 1
              return(sim)
            }
  )
  out <- simInitAndSpades(module = nm, paths = list(modulePath = modulePath))
  # clean up
  unlink(dir(modulePath, pattern = nm, full.names = TRUE), recursive = TRUE)
}
```

`newModuleTests` *Create template testing structures for new modules*

Description

Create template testing structures for new modules

Usage

```
newModuleTests(name, path, open, useGitHub)

## S4 method for signature 'character,character,logical,logical'
newModuleTests(name, path, open, useGitHub)
```

Arguments

name	Character string specifying the name of the new module.
path	Character string. Subdirectory in which to place the new module code file. The default is the current working directory.
open	Logical. Should the new module file be opened after creation? Default TRUE in an interactive session.
useGitHub	Logical indicating whether GitHub will be used. If TRUE (default), creates suitable configuration files (e.g., '.gitignore') and configures basic GitHub actions for module code checking.

Value

NULL (invisibly). Invoked for its side effect of creating new module test files.

Author(s)

Eliot McIntire and Alex Chubaty

See Also

Other module creation helpers: newModule()

---

newObjectsCreated *Show which objects were first created in a* simInit *or* spades *call*

Description

This does an rbindlist(sim$._objectsCreated). This object in the sim records the yellow message that reports on when objects are created.

Usage

```
newObjectsCreated(sim)
```

Arguments

sim	A simList object that contains data.table objects

Value

The data.table of the objects created, alongside the current(sim) at each moment of creation.

newProgressBar *Progress bar*

Description

Shows a progress bar that is scaled to simulation end time.

Usage

```
newProgressBar(sim)

setProgressBar(sim)
```

Arguments

sim	A simList simulation object.

Details

The progress bar object is stored in a separate environment, #' .pkgEnv.

Value

invoked for side effect of creating progress bar

Author(s)

Alex Chubaty and Eliot McIntire

newProject *Create new SpaDES project*

Description

Initialize a project with subdirectories 'cache/', 'modules/', 'inputs/', 'outputs/', and setPaths accordingly. If invoked from Rstudio, will also create a new Rstudio project file.

Usage

```
newProject(name, path, open)

## S4 method for signature 'character,character,logical'
newProject(name, path, open)

## S4 method for signature 'character,character,missing'
newProject(name, path, open)
```

Arguments

name	project name (name of project directory)
path	path to directory in which to create the project directory
open	Logical. Should the new project file be opened after creation? Default TRUE in an interactive session.

Value

invoked for side effect of project file creation

Examples

```
myProjDir <- newProject("myProject", tempdir())

dir.exists(file.path(myProjDir, "cache"))
dir.exists(file.path(myProjDir, "inputs"))
dir.exists(file.path(myProjDir, "modules"))
dir.exists(file.path(myProjDir, "outputs"))
unlink(myProjDir, recursive = TRUE) ## cleanup
```

---

newProjectCode *Create new module code file*

Description

Create new module code file

Usage

```
newProjectCode(name, path, open)

## S4 method for signature 'character,character,logical'
newProjectCode(name, path, open = interactive())
```

Arguments

name	project name (name of project directory)
path	path to directory in which to create the project directory
open	Logical. Should the new project file be opened after creation? Default TRUE in an interactive session.

Value

invoked for side effect of project file creation

Author(s)

Alex Chubaty

noEventWarning *Text for no event with that name*

Description

Provides the text to be sent to `warning` in each module as the default `switch` case.

Usage

```
noEventWarning(sim)
```

Arguments

`sim`	A `simList` simulation object, generally produced by `simInit`.

Value

A text string specifying the event name and module for which there is no event

objectDiagram *Simulation object dependency diagram*

Description

Create a sequence diagram illustrating the data object dependencies of a simulation. Offers a more detailed view of specific objects than does plotting the `depsEdgeList` directly with `moduleDiagram()`.

Usage

```
objectDiagram(sim, ...)

## S4 method for signature 'simList'
objectDiagram(sim, ...)
```

Arguments

`sim`	A `simList` object (typically corresponding to a completed simulation).
`...`	Additional arguments passed to `DiagrammeR::mermaid`. Useful for specifying `height` and `width`.

Value

Plots a sequence diagram, invisibly returning a `DiagrammeR::mermaid` object.

Author(s)

Alex Chubaty

See Also

DiagrammeR::mermaid.

Examples

```
if (requireNamespace("DiagrammeR", quietly = TRUE)) {
  sim <- simInit()
  objectDiagram(sim)
  # if there are lots of objects, may need to increase width and/or height
  objectDiagram(sim, height = 3000, width = 3000)
}
```

---

objectSynonyms *Identify synonyms in a* simList

Description

This will create active bindings amongst the synonyms. To minimize copying, the first one that exists in the character vector will become the "canonical" object. All others named in the character vector will be activeBindings to that canonical one. This synonym list will be assigned to the envir, as an object named objectSynonyms. That object will have an attribute called, bindings indicating which one is the canonical one and which is/are the activeBindings. EXPERIMENTAL: If the objects are removed during a spades call by, say, a module, then at the end of the event, the spades call will replace the bindings. In other words, if a module deletes the object, it will "come back". This may not always be desired.

Usage

```
objectSynonyms(envir, synonyms)
```

Arguments

envir	An environment, which in the context of SpaDES.core is usually a simList to find and/or place the objectSynonyms object.
synonyms	A list of synonym character vectors, such as list(c("age", "ageMap", "age2"), c("veg", "vegMap"))

Details

This is very experimental and only has minimal tests. Please report if this is not working, and under what circumstances (e.g., please submit a reproducible example to our issues tracker)

This function will append any new objectSynonym to any pre-existing objectSynonym in the envir. Similarly, this function assumes transitivity, i.e., if age and ageMap are synonyms, and ageMap and timeSinceFire are synonyms, then age and timeSinceFire must be synonyms.

Value

Active bindings in the envir so that all synonyms point to the same canonical object, e.g., they would be at envir[[synonym[[1]][1]]] and envir[[synonym[[1]][2]]], if a list of length one is passed into synonyms, with a character vector of length two. See examples.

Examples

```
sim <- simInit()

sim$age <- 1:10;
sim <- objectSynonyms(sim, list(c("age", "ageMap")))

identical(sim$ageMap, sim$age)
sim$age <- 4
identical(sim$ageMap, sim$age)
sim$ageMap <- 2:5
sim$ageMap[3] <- 11
identical(sim$ageMap, sim$age)

# Also works to pass it in as an object
objectSynonyms <- list(c("age", "ageMap"))
sim <- simInit(objects = list(objectSynonyms = objectSynonyms))
identical(sim$ageMap, sim$age) # they are NULL at this point
sim$age <- 1:10
identical(sim$ageMap, sim$age) # they are not NULL at this point

## More complicated, with 'updating' i.e., you can add new synonyms to previous
sim <- simInit()
os <- list(c("age", "ageMap"), c("vegMap", "veg"), c("studyArea", "studyArea2"))
os2 <- list(c("ageMap", "timeSinceFire", "tsf"),
            c("systime", "systime2"),
            c("vegMap", "veg"))
sim <- objectSynonyms(sim, os)
sim <- objectSynonyms(sim, os2)

# check
sim$.objectSynonyms
```

---

objs *Extract or replace an object from the simulation environment*

Description

The [[and $ operators provide "shortcuts" for accessing objects in the simulation environment. I.e., instead of using envir(sim)$object or envir(sim)[["object"]], one can simply use sim$object or sim[["object"]].

Usage

```
objs(sim, ...)

## S4 method for signature 'simList'
objs(sim, ...)

objs(sim) <- value

## S4 replacement method for signature 'simList'
objs(sim) <- value

moduleObjects(sim, module, path)

findObjects(objects, sim, module, path)
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
...	passed to ls
value	objects to assign to the simList
module	Character vector of module name(s)
path	The path to the module., i.e., the modulePath. Only relevant if sim not supplied.
objects	A character vector of length >= 1 with name(s) of objects to look for in the metadata. This is used in a grep, meaning it will do partial matching (e.g., "studyArea" will find "studyArea" and "studyAreaLarge"). User can use regular expressions.

Details

objs can take ... arguments passed to ls, allowing, e.g. all.names=TRUE objs<- requires takes a named list of values to be assigned in the simulation environment.

Value

Returns or sets a list of objects in the simList environment.

moduleObjects returns a data.table with 4 columns, module, objectName, type, and desc, pulled directly from the object metadata in the createsOutputs and expectsInputs. These will be determined either from a simList or from the module source code.

findObjects returns a data.table similar to moduleObjects, but with only the objects provided by objects.

See Also

SpaDES.core-package, specifically the section 1.2.1 on Simulation Parameters.

Other functions to access elements of a 'simList' object: .addDepends(), checkpointFile(), envir(), events(), globals(), inputs(), modules(), packages(), params(), paths(), progressInterval(), times()

Examples

```
# findObjects
path <- getSampleModules(tempdir())
findObjects(path = path, module = dir(path), objects = "caribou")
```

---

objSize.simList *Object size for* simList

Description

Recursively, runs reproducible::objSize() on the simList environment, so it estimates the correct size of functions stored there (e.g., with their enclosing environments) plus, it adds all other "normal" elements of the simList, e.g., objSize(completed(sim)). The output is structured into 2 elements: the sim environment and all its objects, and the other slots in the simList (e.g., events, completed, modules, etc.). The returned object also has an attribute, "total", which shows the total size.

Usage

```
## S3 method for class 'simList'
objSize(x, quick = FALSE, recursive = FALSE, ...)
```

Arguments

x	An object
quick	Logical. If FALSE, then an attribute, "objSize" will be added to the returned value, with each of the elements' object size returned also.
recursive	Logical. If TRUE, then, in addition to evaluating the whole object, it will also return the recursive sizes of the elements of a list or environment.
...	Additional arguments (currently unused), enables backwards compatible use.

Value

an estimate of the size of the object, in bytes.

Examples

```
a <- simInit(objects = list(d = 1:10, b = 2:20))
objSize(a)
utils::object.size(a)
```

openModules *Open all modules nested within a base directory*

Description

This is just a convenience wrapper for opening several modules at once, recursively. A module is defined as any file that ends in `.R` or `.r` and has a directory name identical to its filename. Thus, this must be case sensitive.

Usage

```
openModules(name, path)

## S4 method for signature 'character,character'
openModules(name, path)

## S4 method for signature 'missing,missing'
openModules()

## S4 method for signature 'missing,character'
openModules(path)

## S4 method for signature 'character,missing'
openModules(name)

## S4 method for signature 'simList,missing'
openModules(name)
```

Arguments

`name`	Character vector with names of modules to open. If missing, then all modules will be opened within the base directory.
`path`	Character string of length 1. The base directory within which there are only module subdirectories.

Value

NULL (invisibly). All file are open via `file.edit`.

Note

On Windows there is currently a bug in RStudio that prevents the editor from opening when `file.edit` is called. `file.edit` does work if the user types it at the command prompt. A message with the correct lines to copy and paste is provided.

Author(s)

Eliot McIntire

Examples

```
if (interactive())
  openModules("modules")
```

`outputs` *Simulation outputs*

Description

Accessor functions for the `outputs` slots in a `simList` object.

If a module saves a file to disk during events, it can be useful to keep track of the files that are saved e.g., for `saveSimList()` so that all files can be added to the archive. In addition to setting `outputs` at the `simInit` stage, a module developer can also put this in a using any saving mechanism that is relevant (e.g., `qs2::qs_save`, `saveRDS` etc.). When a module event does this it can be useful to register that saved file. `registerOutputs` offers an additional mechanism to do this. See examples.

Usage

```
outputs(sim)

## S4 method for signature 'simList'
outputs(sim)

outputs(sim) <- value

## S4 replacement method for signature 'simList'
outputs(sim) <- value

registerOutputs(filename, sim, ...)

outputArgs(sim)

## S4 method for signature 'simList'
outputArgs(sim)

outputArgs(sim) <- value

## S4 replacement method for signature 'simList'
outputArgs(sim) <- value
```

Arguments

`sim`	A `simList`. If missing, then the function will search in the call stack, so it will find it if it is in a `SpaDES` module.

value	The object to be stored at the slot. See Details.
filename	The filename to register in the outputs(sim) data.frame. If missing, an attempt will be made to search for either a file or filename argument in the call itself. This means that this function can be used with the pipe, as long as the returned return from the upstream pipe function is a filename or if it is NULL (e.g., saveRDS), then it will find the file argument and use that.
...	Not used.

Details

These functions are one of three mechanisms to add information about which output files to save.

1. As arguments to a simInit call. Specifically, inputs or outputs. See ?simInit.
2. With the outputs(simList) function call.
3. By adding a function called .inputObjects inside a module, which will be executed during the simInit call. This last way is the most "modular" way to create default data sets for your model.

See below for more details.

Note using registerOutputs: a user can pass any other arguments to registerOutputs that are in the outputs(sim) data.frame, such as objectName, fun, package, though these will not be used to save the files as this function is only about registering an output that has already been saved.

Value

A simList which will be the sim passed in with a new object registered in the outputs(sim)

outputs function or argument in simInit

outputs accepts a data.frame similar to the inputs data.frame, but with up to 7 columns.

objectName	required, character string indicating the name of the object in the simList that will be saved to disk (witho
file	optional, a character string indicating the file path to save to. The default is to concatenate objectName wit
fun	optional, a character string indicating the function to use to save that file. The default is saveRDS()
package	optional character string indicating the package in which to find the fun);
saveTime	optional numeric, indicating when in simulation time the file should be saved. The default is the lowest pric
arguments	optional list of lists of named arguments, one list for each fun. For example, if fun = "write.csv", argume
eventPriority	optional numeric setting the priority given to saving the specified object. If not set, it defaults to .last().

See the modules vignette for more details (browseVignettes("SpaDES.core")).

Note

The automatic file type handling only adds the correct extension from a given fun and package. It does not do the inverse, from a given extension find the correct fun and package.

See Also

registerOutputs() which enables files that are saved to be added to the simList using the outputs(sim) mechanism, so the files that are saved during a module event can be tracked at the simList level. saveSimList() which will optionally add all the outputs that are tracked into an archive.

Plots(), outputs()

Examples

```
#######################
# outputs
#######################

tmpdir <- file.path(tempdir(), "outputs") |> checkPath(create = TRUE)
tmpFile <- file.path(tmpdir, "temp.rds")
tempObj <- 1:10

# Can add data.frame of outputs directly into simInit call
sim <- simInit(objects = c("tempObj"),
               outputs = data.frame(objectName = "tempObj"),
               paths = list(outputPath = tmpdir))
outputs(sim) # To see what will be saved, when, what filename
sim <- spades(sim)
outputs(sim) # To see that it was saved, when, what filename

# Also can add using assignment after a simList object has been made
sim <- simInit(objects = c("tempObj"), paths = list(outputPath = tmpdir))
outputs(sim) <- data.frame(objectName = "tempObj", saveTime = 1:10)
sim <- spades(sim)
outputs(sim) # To see that it was saved, when, what filename.

# can do highly variable saving
tempObj2 <- paste("val", 1:10)
df1 <- data.frame(col1 = tempObj, col2 = tempObj2)
sim <- simInit(objects = c("tempObj", "tempObj2", "df1"),
  paths = list(outputPath = tmpdir))
outputs(sim) <- data.frame(
     objectName = c(rep("tempObj", 2), rep("tempObj2", 3), "df1"),
     saveTime = c(c(1, 4), c(2, 6, 7), end(sim)),
     fun = c(rep("saveRDS", 5), "write.csv"),
     package = c(rep("base", 5), "utils"),
     stringsAsFactors = FALSE)
# since write.csv has a default of adding a column, x, with rownames, must add additional
#   argument for 6th row in data.frame (corresponding to the write.csv function)
outputArgs(sim)[[6]] <- list(row.names = FALSE)
sim <- spades(sim)
outputs(sim)

# read one back in just to test it all worked as planned
newObj <- read.csv(dir(tmpdir, pattern = "year10.csv", full.name = TRUE))
newObj
```

```
# using saving with SpaDES-aware methods
# To see current ones SpaDES can do
.saveFileExtensions()

library(terra)
ras <- rast(ncol = 4, nrow = 5)
ras[] <- 1:20

sim <- simInit(objects = c("ras"), paths = list(outputPath = tmpdir))
outputs(sim) <- data.frame(
  file = "test",
  fun = "writeRaster",
  package = "terra",
  objectName = "ras",
  stringsAsFactors = FALSE)

simOut <- spades(sim)
outputs(simOut)
newRas <- rast(dir(tmpdir, full.name = TRUE, pattern = ".tif")[1])
all.equal(newRas, ras) # Should be TRUE
# Clean up after
unlink(tmpdir, recursive = TRUE)
# For `registerOutputs`
sim <- simInit()
# This would normally be a save call, e.g., `writeRaster`
tf <- reproducible::tempfile2(fileext = ".tif")
sim <- registerOutputs(sim, filename = tf)

# Using a pipe
tf <- reproducible::tempfile2(fileext = ".rds")
sim$a <- 1
sim <- saveRDS(sim$a, tf) |> registerOutputs()
# confirm:
outputs(sim) # has object --> saved = TRUE
```

---

packages *Get module or simulation package dependencies*

Description

Get module or simulation package dependencies

Usage

```
packages(sim, modules, paths, filenames, envir, clean = FALSE, ...)

## S4 method for signature 'ANY'
packages(sim, modules, paths, filenames, envir, clean = FALSE, ...)
```

Arguments

sim	A simList object.
modules	Character vector, specifying the name or vector of names of module(s)
paths	Character vector, specifying the name or vector of names of paths(s) for those modules. If path not specified, it will be taken from getOption("spades.modulePath"), which is set with setPaths())
filenames	Character vector specifying filenames of modules (i.e. combined path & module. If this is specified, then modules and path are ignored.
envir	Optional environment in which to store parsed code. This may be useful if the same file is being parsed multiple times. This function will check in that environment for the parsed file before parsing again. If the envir is transient, then this will have no effect.
clean	Optional logical. If TRUE, it will scrub any references to GitHub repositories, e.g., "PredictiveEcology/reproducible" will be returned as "reproducible".
...	All simInit parameters.

Value

A sorted character vector of package names.

Author(s)

Alex Chubaty & Eliot McIntire

See Also

Other functions to access elements of a 'simList' object: .addDepends(), checkpointFile(), envir(), events(), globals(), inputs(), modules(), objs(), params(), paths(), progressInterval(), times()

---

paramCheckOtherMods *Test and update a parameter against same parameter in other modules*

Description

This function is intended to be part of module code and will test whether the value of a parameter within the current module matches the value of the same parameter in other modules. This is a test for parameters that might expect to be part of a params = list(.globals = list(someParam = "test")) passed to simInit().

Usage

```
paramCheckOtherMods(
  sim,
  paramToCheck,
  moduleToUse = "all",
  ifSetButDifferent = c("error", "warning", "message", "silent"),
  verbose = getOption("reproducible.verbose")
)
```

Arguments

sim	A simList object
paramToCheck	A character string, length one, of a parameter name to check and compare between the current module and one or more or all others
moduleToUse	A character vector of module names to check against. This can be "all" which will compare against all other modules.
ifSetButDifferent	A character string indicating whether to "error" the default, or send a "warning", message or just silently continue (any other value).
verbose	Logical or Numeric, follows reproducible.verbose value by default.

Details

It is considered a "fail" under several conditions:

1. current module has a value that is not NULL or "default" and another module has a different value;
2. there is more than one value for the paramToCheck in the other modules, so it is ambiguous which one to return.

Either the current module is different than other modules, unless it is "default" or NULL.

Value

If the value of the paramToCheck in the current module is either NULL or "default", and there is only one other value across all modules named in moduleToUse, then this will return a character string with the value of the single parameter value in the other module(s). It will return the current value if there are no other modules with the same parameter.

params *Get and set simulation parameters*

Description

params, P and Par (an active binding, like "mod") access the parameter slot in the simList. params has a replace method, so can be used to update a parameter value.

Usage

```
params(sim)

## S4 method for signature 'simList'
params(sim)

params(sim) <- value

## S4 replacement method for signature 'simList'
params(sim) <- value

P(sim, param, module)

P(sim, param, module) <- value

parameters(sim, asDF = FALSE)

## S4 method for signature 'simList'
parameters(sim, asDF = FALSE)
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The parameter value to be set (in the corresponding module and param).
param	Optional character string indicating which parameter to choose.
module	Optional character string indicating which module params should come from.
asDF	Logical. For parameters, if TRUE, this will produce a single data.frame of all model parameters. If FALSE, then it will return a data.frame with 1 row for each parameter within nested lists, with the same structure as params.

Details

parameters will extract only the metadata with the metadata defaults, NOT the current values that may be overwritten by a user. See examples.

Value

Returns or sets the value of the slot from the `simList` object.

Note

The differences between `P()`, `params()` and being explicit with passing arguments are mostly a question of speed and code compactness. The computationally fastest way to get a parameter is to specify `moduleName` and parameter name, as in: `P(sim, "paramName", "moduleName")` (replacing `moduleName` and `paramName` with your specific module and parameter names), but it is more verbose than `P(sim)$paramName`. Note: the important part for speed (e.g., 2-4x faster) is specifying the `moduleName`. Specifying the parameter name is <5% faster.

See Also

SpaDES.core-package, specifically the section 1.2.1 on Simulation parameters.

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `events()`, `globals()`, `inputs()`, `modules()`, `objs()`, `packages()`, `paths()`, `progressInterval()`, `times()`

Examples

```
s <- simInit()
# add a parameter to tmp module
params(s)$tmp <- list(a = 1)

# Only work inside a module, inside a function with `sim` is an argument
# P(s, "a") # get "a" parameter inside the current module
# Par$a     # same. Get "a" parameter inside the current module

if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
  opts <- options("spades.moduleCodeChecks" = FALSE) # not necessary for example
  modules <- list("randomLandscapes")
  paths <- list(modulePath = getSampleModules(tempdir()))
  mySim <- simInit(modules = modules, paths = paths,
                   params = list(.globals = list(stackName = "landscape")))

  # update some parameters using assignment -- currently only params will work
  params(mySim)$randomLandscapes$nx <- 200
  params(mySim)$randomLandscapes$ny <- 200

  parameters(mySim) # Does not contain these user overridden values

  # These next 2 are same here because they are not within a module
  P(mySim)          # Does contain the user overridden values
  params(mySim)     # Does contain the user overridden values

  # NOTE -- deleting a parameter will affect params and P, not parameters
  params(mySim)$randomLandscapes$nx <- NULL
  params(mySim)$randomLandscapes$ny <- NULL
```

```
  parameters(mySim) # Shows nx and ny

  # These next 2 are same here because they are not within a module
  P(mySim)          # nx and ny are Gone
  params(mySim)     # nx and ny are Gone

  options(opts) # reset
}
```

---

paths *Specify paths for modules, inputs, outputs, and temporary rasters*

Description

Accessor functions for the paths slot in a simList object.

dataPath will return file.path(modulePath(sim), currentModule(sim), "data"). dataPath, like currentModule,is namespaced. This means that when it is used inside a module, then it will return *that model-specific* information. For instance, if used inside a module called "movingAgent", then currentModule(sim) will return "movingAgent", and dataPath(sim) will return file.path(modulePath(sim), "movingAgent", "data")

Usage

```
paths(sim)

## S4 method for signature 'simList'
paths(sim)

paths(sim) <- value

## S4 replacement method for signature 'simList'
paths(sim) <- value

cachePath(sim)

## S4 method for signature 'simList'
cachePath(sim)

cachePath(sim) <- value

## S4 replacement method for signature 'simList'
cachePath(sim) <- value

inputPath(sim)

## S4 method for signature 'simList'
inputPath(sim)
```

```
inputPath(sim) <- value

## S4 replacement method for signature 'simList'
inputPath(sim) <- value

outputPath(sim)

## S4 method for signature 'simList'
outputPath(sim)

outputPath(sim) <- value

## S4 replacement method for signature 'simList'
outputPath(sim) <- value

figurePath(sim)

## S4 method for signature 'simList'
figurePath(sim)

logPath(sim)

## S4 method for signature 'simList'
logPath(sim)

modulePath(sim, module)

## S4 method for signature 'simList'
modulePath(sim, module)

modulePath(sim) <- value

## S4 replacement method for signature 'simList'
modulePath(sim) <- value

scratchPath(sim)

## S4 method for signature 'simList'
scratchPath(sim)

scratchPath(sim) <- value

## S4 replacement method for signature 'simList'
scratchPath(sim) <- value

rasterPath(sim)
```

```
## S4 method for signature 'simList'
rasterPath(sim)

rasterPath(sim) <- value

## S4 replacement method for signature 'simList'
rasterPath(sim) <- value

terraPath(sim)

## S4 method for signature 'simList'
terraPath(sim)

terraPath(sim) <- value

## S4 replacement method for signature 'simList'
terraPath(sim) <- value

dataPath(sim)

## S4 method for signature 'simList'
dataPath(sim)
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The parameter value to be set (in the corresponding module and param).
module	The optional character string of the module(s) whose paths are desired. If omitted, will return all module paths, if more than one exist.

Details

These are ways to add or access the file paths used by spades(). There are five file paths: cachePath, modulePath, inputPath, outputPath, and rasterPath. Each has a function to get or set the value in a simList object. If no paths are specified, the defaults are as follows:

- cachePath: getOption("reproducible.cachePath");
- inputPath: getOption("spades.modulePath");
- modulePath: getOption("spades.inputPath");
- outputPath: getOption("spades.outputPath");
- rasterPath: file.path(getOption("spades.scratchPath"), "raster");
- scratchPath: getOption("spades.scratchPath");
- terraPath: file.path(getOption("spades.scratchPath"), "terra")

Value

Returns or sets the value of the slot from the simList object.

See Also

SpaDES.core-package, specifically the section 1.2.4 on Simulation Paths.

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `events()`, `globals()`, `inputs()`, `modules()`, `objs()`, `packages()`, `params()`, `progressInterval()`, `times()`

Plot,simList-method *Plot method for* simList *objects*

Description

Extends `quickPlot::Plot` for `simList` objects.

Usage

```
## S4 method for signature 'simList'
Plot(
  ...,
  new = FALSE,
  addTo = NULL,
  gp = gpar(),
  gpText = gpar(),
  gpAxis = gpar(),
  axes = FALSE,
  speedup = 1,
  size = 5,
  cols = NULL,
  col = NULL,
  zoomExtent = NULL,
  visualSqueeze = NULL,
  legend = TRUE,
  legendRange = NULL,
  legendText = NULL,
  pch = 19,
  title = NULL,
  na.color = "#FFFFFF00",
  zero.color = NULL,
  length = NULL,
  arr = NULL,
  plotFn = "plot",
  verbose = getOption("quickPlot.verbose")
)
```

Arguments

...	A combination of spatialObjects or non-spatial objects. For many object classes, there are specific Plot methods. Where there are no specific ones, the base plotting will be used internally. This means that for objects with no specific Plot methods, many arguments, such as addTo, will not work. See details.
new	Logical. If TRUE, then the previous named plot area is wiped and a new one made; if FALSE, then the ... plots will be added to the current device, adding or rearranging the plot layout as necessary. Default is FALSE. This currently works best if there is only one object being plotted in a given Plot call. However, it is possible to pass a list of logicals to this, matching the length of the ... objects. Use clearPlot to clear the whole plotting device. NOTE if TRUE: *Everything that was there, including the legend and the end points of the colour palette, will be removed and re-initiated.*
addTo	Character vector, with same length as .... This is for overplotting, when the overplot is not to occur on the plot with the same name, such as plotting a SpatialPoints* object on a RasterLayer.
gp	A gpar object, created by gpar(), to change plotting parameters (see **grid** package).
gpText	A gpar object for the title text. Default gpar(col = "black").
gpAxis	A gpar object for the axes. Default gpar(col = "black").
axes	Logical or "L", representing the left and bottom axes, over all plots.
speedup	Numeric. The factor by which the number of pixels is divided by to plot rasters. See Details.
size	Numeric. The size, in points, for SpatialPoints symbols, if using a scalable symbol.
cols	(also col) Character vector or list of character vectors of colours. See details.
col	(also cols) Alternative to cols to be consistent with plot. cols takes precedence, if both are provided.
zoomExtent	An Extent object. Supplying a single extent that is smaller than the rasters will call a crop statement before plotting. Defaults to NULL. This occurs after any downsampling of rasters, so it may produce very pixelated maps.
visualSqueeze	Numeric. The proportion of the white space to be used for plots. Default is 0.75.
legend	Logical indicating whether a legend should be drawn. Default is TRUE.
legendRange	Numeric vector giving values that, representing the lower and upper bounds of a legend (i.e., 1:10 or c(1,10) will give same result) that will override the data bounds contained within the grobToPlot.
legendText	Character vector of legend value labels. Defaults to NULL, which results in a pretty numeric representation. If Raster* has a Raster Attribute Table (rat; see **raster** package), this will be used by default. Currently, only a single vector is accepted. The length of this must match the length of the legend, so this is mostly useful for discrete-valued rasters.
pch	see ?par.

title	Logical or character string. If logical, it indicates whether to print the object name as the title above the plot. If a character string, it will print this above the plot. NOTE: the object name is used with addTo, not the title. Default NULL, which means print the object name as title, if no other already exists on the plot, in which case, keep the previous title.
na.color	Character string indicating the colour for NA values. Default transparent.
zero.color	Character string indicating the colour for zero values, when zero is the minimum value, otherwise, zero is treated as any other colour. Default transparent.
length	Numeric. Optional length, in inches, of the arrow head.
arr	A vector of length 2 indicating a desired arrangement of plot areas indicating number of rows, number of columns. Default NULL, meaning let Plot function do it automatically.
plotFn	An optional function name to do the plotting internally, e.g., "barplot" to get a barplot() call. Default "plot".
verbose	Numeric or logical. If TRUE or >0, then messages will be shown. If FALSE or 0, most messages will be suppressed.

Details

See quickPlot::Plot. This method strips out stuff from a simList class object that would make it otherwise not reproducibly digestible between sessions, operating systems, or machines. This will likely still not allow identical digest results across R versions.

Value

invoked for side effect of plotting

See Also

quickPlot::Plot

Plots Plot *wrapper intended for use in a SpaDES module*

Description

This is a single function call that allows a user to change which format in which the plots will occur. Specifically, the two common formats would be to "screen" or to disk as an image file, such as "png". *This has currently been tested with* ggplot2*,* RasterLayer*, and* tmap *objects.* The default (or change with e.g., fn = "print", usePlot = FALSE) uses Plot internally, so individual plots may be rearranged. When saved to disk (e.g., via type = 'png'), then Plot will not be used and the single object that is the result of this Plots call will be saved to disk. This function requires at least 2 things: a plotting function and arguments passed to that function (which could include data, but commonly would simply be named arguments required by fn). See below and examples.

Usage

```
Plots(
  data,
  fn,
  filename,
  types = quote(params(sim)[[currentModule(sim)]]$.plots),
  path = quote(figurePath(sim)),
  .plotInitialTime = quote(params(sim)[[currentModule(sim)]]$.plotInitialTime),
  ggsaveArgs = list(),
  usePlot = getOption("spades.PlotsUsePlot", FALSE),
  deviceArgs = list(),
  envir = parent.frame(),
  useCache = FALSE,
  ...
)
```

Arguments

data	An (optional) arbitrary data object. If supplied, it will be passed as the first argument to Plot function, and should contain all the data required for the inner plotting. If passing a RasterLayer, it may be a good idea to set names(RasterLayer) so that multiple layers can be plotted without overlapping each other. When a custom fn is used and all arguments for fn are supplied and named, then this can be omitted. See examples.
fn	An arbitrary plotting function. If not provided, defaults to using quickPlot::Plot
filename	A name that will be the base for the files that will be saved, i.e, do not supply the file extension, as this will be determined based on types. If a user provides this as an absolute path, it will override the path argument.
types	Character vector, zero or more of types. If used within a module, this will be deduced from the P(sim)$type and can be omitted. See below.
path	Currently a single path for the saved objects on disk. If filename is supplied as an absolute path, path will be set to dirname(filename), overriding this argument value.
.plotInitialTime	A numeric. If NA then no visual on screen. Anything else will have visuals plotted to screen device. This is here for backwards compatibility. A developer should set in the module to the intended initial plot time and leave it, i.e., *not* NA.
ggsaveArgs	An optional list of arguments passed to ggplot2::ggsave
usePlot	Logical. If TRUE, the default, then the plot will occur with quickPlot::Plot, so it will be arranged with previously existing plots.
deviceArgs	An optional list of arguments passed to one of png, pdf, tiff, bmp, or jgeg. This is useful when the plotting function is not creating a ggplot object, e.g., plotting a RasterLayer.
envir	The environment where the data argument should be evaluated if it is a call. Normally, this should be left at its default, parent.frame().

useCache	Logical or character vector. If TRUE, caching is enabled for all non-screen output types. If a character vector, caching is enabled only for the matching types. Default is FALSE.
...	Anything needed by fn, all named.

Details

- type
  - "screen" – Will plot to the current device, normally a plot window
  - "object" – Will save the plot object, e.g., ggplot object
  - "raw" – Will save the raw data prior to plotting, e.g., the data argument
  - "png" – or any other type save-able with ggsave

Value

Called for its side effect of plot creation.

Recording of files saved

In cases where files are saved, and where Plots is used within a SpaDES module, the file(s) that is/are saved will be appended to the outputs slot of the simList of the module. This will, therefore, keep a record of figures saved *within* the simList

Note

This is still experimental and could change in the next release.

Plots now has experimental support for "just a Plot call", but with types specified. See examples. The devices to save on disk will have some different behaviours to the screen representation, since "wiping" an individual plot on a device doesn't exist for a file device.

This offers up to 4 different actions for a given plot:

- To screen device
- To disk as raw data (limited testing)
- To disk as a saved plot object (limited testing)
- To disk as a '.png' or other image file, e.g., '.pdf'

To turn off plotting both to screen and disk, set both .plotInititalTime = NA and .plots = NA or any other value that will not trigger a TRUE with a grepl with the types argument (e.g., "" will omit all saving).

Examples

```
# Note: if this is used inside a SpaDES module, do not define this
#  function inside another function. Put it outside in a normal
#  module script. Otherwise, it will cause a memory leak.
if (requireNamespace("ggplot2")) {
  fn <- function(d)
    ggplot2::ggplot(d, ggplot2::aes(a)) +
```

```
  ggplot2::geom_histogram()
sim <- simInit()
sim$something <- data.frame(a = sample(1:10, replace = TRUE))

Plots(data = sim$something, fn = fn,
      types = c("png"),
      path = file.path(tempdir(), "figures"),
      filename = tempfile(),
      .plotInitialTime = 1)

# plot to active device and to png
Plots(
  data = sim$something, fn = fn,
  types = c("png", "screen"),
  path = file.path(tempdir(), "figures"),
  filename = tempfile(),
  .plotInitialTime = 1
)

# Can also be used like quickPlot::Plot, but with control over output type
r <- terra::rast(terra::ext(0,10,0,10),
                 vals = sample(1:3, size = 100, replace = TRUE))
Plots(r, types = c("screen", "png"), filename = tempfile(),
      deviceArgs = list(width = 700, height = 500),
      usePlot = TRUE)

# with ggplotify, Plots can also be used to plot/save
# non-ggplot objects:


if (require("ggplotify")) {
  if (!require("lattice")) stop("please install lattice")

  p1 <- densityplot(~mpg|cyl, data=mtcars)
  Plots(data = p1, fn = as.ggplot, filename = tempfile(),
        ggsaveArgs = list(width = 5, height = 4, dpi = 300,
                          bg = "white", units = "in"),
        types = c("screen", "png"),
        .plotInitialTime = 1)
}
} # end ggplot
unlink("figures") # clean up
# end of dontrun
```

`priority` *Event priority*

Description

Preset event priorities: 1 = first (highest); 5 = normal; 10 = last (lowest).

Usage

```
.first()

.highest()

.last()

.lowest()

.normal()
```

Value

numeric of length 1.

Author(s)

Alex Chubaty

---

progressInterval *Get and set simulation progress bar details*

Description

The progress bar can be set in two ways in SpaDES. First, by setting values in the `.progress` list element in the params list element passed to `simInit()`. Second, at the `spades()` call itself, which can be simpler. See examples.

Usage

```
progressInterval(sim)

## S4 method for signature 'simList'
progressInterval(sim)

progressInterval(sim) <- value

## S4 replacement method for signature 'simList'
progressInterval(sim) <- value

progressType(sim)

## S4 method for signature 'simList'
progressType(sim)

progressType(sim) <- value
```

```
## S4 replacement method for signature 'simList'
progressType(sim) <- value
```

Arguments

sim	A simList object from which to extract element(s) or in which to replace element(s).
value	The parameter value to be set (in the corresponding module and param).

Details

Progress Bar: Progress type can be one of "text", "graphical", or "shiny". Progress interval can be a numeric. These both can get set by passing a .progress = list(type = "graphical", interval = 1) into the simInit call. See examples.

Value

for progressInterval, a numeric corresponding to the progress update interval; for progressInterval<-, an updated simList object.

See Also

Other functions to access elements of a 'simList' object: .addDepends(), checkpointFile(), envir(), events(), globals(), inputs(), modules(), objs(), packages(), params(), paths(), times()

Examples

```
if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
opts <- options("spades.moduleCodeChecks" = FALSE) # not necessary for example
mySim <- simInit(
  times = list(start=0.0, end=100.0),
  params = list(.globals = list(stackName = "landscape"),
  .progress = list(type = "text", interval = 10),
  checkpoint = list(interval = 10, file = "chkpnt.RData")),
  modules = list("randomLandscapes"),
  paths = list(modulePath = getSampleModules(tempdir()))
)

# progress bar
progressType(mySim) # "text"
progressInterval(mySim) # 10

# parameters
params(mySim) # returns all parameters in all modules
              # including .global, .progress, checkpoint
globals(mySim) # returns only global parameters

# checkpoint
checkpointFile(mySim) # returns the name of the checkpoint file
```

```
                      # In this example, "chkpnt.RData"
checkpointInterval(mySim) # 10

options(opts) # reset
}
```

`rasterCreate` *Simple wrapper to load any* `Raster*` *object*

Description

This wraps either `raster::raster`, `raster::stack`, `raster::brick`, or `terra::rast`, allowing a single function to be used to create a new object of the same class as a template. This works for all `Raster*` and `SpatRaster` class templates.

Usage

```
rasterCreate(x, ...)

## Default S3 method:
rasterCreate(x, ...)
```

Arguments

`x`	An object, notably a `Raster*` object. All others will simply be passed through with no effect.
`...`	Passed to `raster::raster`, `raster::stack`, or `raster::brick`

Value

a new (empty) object of same class as the original.

Methods (by class)

- `rasterCreate(default)`: Simply passes through argument with no effect

`rasterToMemory` *Read raster to memory*

Description

Wrapper to the `raster` function, that creates the raster object in memory, even if it was read in from file. There is the default method which is just a pass through, so this can be safely used on large complex objects, recursively, e.g., a `simList`.

Usage

```
rasterToMemory(x, ...)

## S4 method for signature 'list'
rasterToMemory(x, ...)

## S4 method for signature 'character'
rasterToMemory(x, ...)

## S4 method for signature 'ANY'
rasterToMemory(x, ...)

## S4 method for signature 'simList'
rasterToMemory(x, ...)
```

Arguments

`x`	An object passed directly to the function raster (e.g., character string of a filename).
`...`	Additional arguments to `raster::raster`, `raster::stack`, or `raster::brick`.

Value

A raster object whose values are stored in memory.

Author(s)

Eliot McIntire and Alex Chubaty

See Also

`raster()`, `terra::rast()`.

remoteFileSize *Determine the size of a remotely hosted file*

Description

Defunct. Will be removed by mid-2023.

Usage

```
remoteFileSize(url)
```

Arguments

url	The url of the remote file.

Value

A numeric indicating the size of the remote file in bytes.

Author(s)

Eliot McIntire and Alex Chubaty

restartR *Restart R programmatically*

Description

This will attempt to restart the R session, reloading all packages, and saving and reloading the simList. Currently, this is not intended for general use: it has many specialized pieces for using inside a spades call. The main purpose for doing this is to clear memory leaks (possibly deep in R https://github.com/r-lib/fastmap) that are not fully diagnosed. *This is still very experimental*. This should only be used if there are RAM limitations being hit with long running simulations. It has been tested to work Linux within Rstudio and at a terminal R session. The way to initiate restarting of R is simply setting the spades.restartRInterval or setting the equivalent parameter in the restartR core module via: simInit(..., params = list(.restartR = list(.restartRInterval = 1)), ...) greater than 0, which is the default, e.g., options("spades.restartRInterval" = 100). This is only intended to restart a simulation in exactly the same place as it was (i.e., cannot change machines), and because of the restart, the assignment of the spades call will be either to sim or the user must make such an assignment manually, e.g., sim <- savedSimEnv()$.sim, or perhaps, the safer sim <- Copy(savedSimEnv()$.sim). This is stated in a message.

Usage

```
restartR(
  sim,
  reloadPkgs = TRUE,
  .First = NULL,
  .RDataFile = getOption("spades.restartR.RDataFilename"),
  restartDir = getOption("spades.restartR.restartDir", NULL)
)
```

Arguments

sim	Required. A simList to be retained through the restart.
reloadPkgs	Logical. If TRUE, it will attempt to reload all the packages as they were in previous session, in the same order. If FALSE, it will load no packages beyond normal R startup. Default TRUE.
.First	A function to save to '~/.qs2' which will be loaded at restart from '~/.qs2' and run. Default is NULL, meaning it will use the non-exported SpaDES.core:::First. If a user wants to make a custom First file, it should built off that one.
.RDataFile	A filename for saving the simList. Defaults to getOption("spades.restartR.filename"), and the directory will be in restartDir. The simulation time will be mid-pended to this name, as in: basename(file), "_time", paddedFloatToChar(time(sim), padL = ncha
restartDir	A character string indicating root directory to save simList and other ancillary files during restart. Defaults to getOption("spades.restartR.restartDir", NULL). If NULL, then it will try, in order, outputPath(sim), modulePath(sim), inputPath(sim), cachePath(sim), taking the first one that is not inside the tempdir(), which will disappear during restart of R. The actual directory for a given spades call that is restarting will be: file.path(restartDir, "restartR", paste0(sim[[._txtStartClockTime]], "_", .rndString)). The random string is to prevent parallel processes that started at the same clock time from colliding.

Details

The process responds to several options. Though under most cases, the default behaviour should suffice. These are of 3 types: restartRInterval the arguments to restartR and the arguments to saveSimList, these latter two using a dot to separate the function name and its argument. The defaults for two key options are: options("spades.restartR.restartDir" = NULL, meaning use file.path(restartDir, "restartR", paste0(sim[[._txtStartClockTime]], "_", .rndString)) and options("spades.saveSimList.fileBackend" = 0), which means don't do anything with raster-backed files. See specific functions for defaults and argument meanings. The only difference from the default function values is with saveSimList argument fileBackend = FALSE during restartR by default, because it is assumed that the file backends will still be intact after a restart, so no need to move them all to memory.

Value

invoked for side effect of restarting the R session

Note

Because of the restarting, the object name of the original assignment of the spades call can not be preserved. The spades call will be assigned to sim in the .GlobalEnv.

Because this function is focused on restarting during a spades call, it will remove all objects in the .GlobalEnv, emulating q("no"). If the user wants to keep those objects, then they should be saved to disk immediately before the spades call. This can then be recovered immediately after the return from the spades call.

To keep the saved simList, use options("spades.restartR.clearFiles" = TRUE). The default is to treat these files as temporary files and so will be removed.

---

restartSpades *Restart an interrupted simulation*

Description

This is experimental and has not been thoroughly tested. Use with caution. If there is an error during an event, this function will rewind the simulation to a state numEvents prior to the event that led to the error. The developer may then modify the source code of the module that caused the break and resume the simulation.

This is experimental and has not been thoroughly tested. Use with caution. This is the simInit/.inputObjects analogue of restartSpades(). If a module's .inputObjects errors during simInit() and options('spades.recoveryMode') was set to TRUE or a numeric (the default, 1), the interrupted simList is saved to savedSimEnv()$.sim with a list .recoverableObjs recording the state of each module's input objects at the start of its .inputObjects. restartSimInit() rewinds the simList to the start of the interrupted .inputObjects (i.e., numEvents prior), re-parses the (presumably fixed) module source, then resumes simInit by running the remaining modules' .inputObjects and completing the initialization.

Usage

```
restartSpades(
  sim = NULL,
  module = NULL,
  numEvents = 1L,
  restart = TRUE,
  verbose = getOption("reproducible.verbose", 1L),
  ...
)

saveState(filename, ...)

restartSimInit(
  sim = NULL,
  module = NULL,
  numEvents = 1L,
```

```
  restart = TRUE,
  verbose = getOption("reproducible.verbose", 1L),
  ...
)

restartOrSimInitAndSpades(ll, file, reset = getOption("spades.resetRestart"))
```

Arguments

sim	A simList or a filename that will load a simList, e.g., from saveState or saveSimList. If not supplied (the default), this will take the sim from savedSimEnv()$.sim, i.e., the one that was interrupted
module	A character string naming the module whose .inputObjects caused the error and whose source code was fixed. This module will be re-parsed into the simList. If NULL (default), it is taken from the most recent recovery snapshot.
numEvents	Numeric. Default 1L (rewind only the interrupted module's .inputObjects). Use Inf to rewind all recoverable .inputObjects.
restart	Logical. If TRUE, then the call to spades will be made, i.e., restarting the simulation. If FALSE, then it will return a new simList with the module code parsed into the simList
verbose	Logical or Numeric, follows reproducible.verbose value by default.
...	Passed to spades, e.g., debug, .plotInitialTime. If the interrupted spades() call used an events filter (to run only certain events), the same filter is reused automatically on restart; pass a new events argument here to override it.
filename	The filename to save the sim state. saveState is a wrapper around restartSpades and saveSimList. You can pass arguments to the . . . that will be passed to saveSimList, such as modules, inputs, outputs.
ll	A list of elements that would be passed to simInit, such as modules.
file	An optional file that has a saved simList, e.g., from saveSimList or saveState.
reset	Logical. If TRUE, then it will force simInitAndSpades to be called even if there is saved sim available.

Details

If options('spades.recoveryMode') is set to TRUE or a numeric (default 1), then there will be a list in the simList called .recoverableObjs. These record the elements of simList that have changed over a number of events equal to the number chosen for options('spades.recoveryMode'). The restartSpades function then uses this list to rewind numEvents backwards from the first event in events(sim) (likely the one that caused the error).

The random number seed will be reset to the state it was at the start of the earliest event recovered, thereby returning to the exact stochastic simulation trajectory.

The random number seed is reset to its state at the start of the earliest recovered .inputObjects, so that any stochastic defaults are reproduced exactly.

Value

A simList as if spades had been called on a simList.

A simList as if simInit() had completed (when restart = TRUE), or the rewound simList with the fixed module re-parsed (when restart = FALSE).

A simList, that has been "executed" until end(sim), if it does not hit an error.

Note

The simList will be in the state it was numEvents prior to the event that led to the error (although some objects, e.g., on disk, may have already been modified).

Examples

```
# options("spades.recoveryMode" = 1) # now the default
s <- simInit()
s <- spades(s) # if this is interrupted or fails
## the following line will not work if the previous line didn't fail:

## don't need to specify `sim` if previous line fails;
## will take from savedSimEnv()$.sim automatically
s <- restartSpades(s)
```

---

savedSimEnv *Retrieve environment for saving interrupted simulations*

Description

If the user sets options(reproducible.memoisePersist = TRUE), the global environment will be used, otherwise, a package environment.

Usage

```
savedSimEnv(envir = .GlobalEnv)
```

Arguments

envir	an environment to use to store the .sim (simList) object. default is to use the user's global environment (.GlobalEnv).

Value

An environment: envir if options(reproducible.memoisePersist = TRUE), otherwise the SpaDES.core package environment used to hold the saved simList.

saveFiles *Save objects using* .saveObjects *in* params *slot of* simInit

Description

In the simInit() call, a parameter called .saveObjects can be provided in each module. This must be a character string vector of all object names to save. These objects will then be saved whenever a call to saveFiles is made.

Usage

```
saveFiles(sim)
```

Arguments

sim	A simList simulation object.

Details

The file names will be equal to the object name plus time(sim) is appended at the end. The files are saved as .rds files, meaning, only one object gets saved per file.

For objects saved using this function, the module developer must create save events that schedule a call to saveFiles.

If this function is used outside of a module, it will save all files in the outputs(sim) that are scheduled to be saved at the current time in the simList.

There are several ways to save objects using SpaDES.

Value

(invisibly) the modified sim object. invoked for side effect of saving the simulation to file.

Model-level saving

Using the outputs slot in the simInit() call. See example in simInit(). This can be convenient because it gives overall control of many modules at a time, and it gets automatically scheduled during the simInit() call.

Module-level saving

Using the saveFiles function inside a module. This must be accompanied by a .saveObjects vector or list element in the params slot in the simList(). Usually a module developer will create this method for future users of their module.

Custom saving

A module developer can save any object at any time inside their module, using standard R functions for saving R objects (e.g., save or saveRDS). This is the least modular approach, as it will happen whether a module user wants it or not.

Note

It is not possible to schedule separate saving events for each object that is listed in the `.saveObjects`.

Author(s)

Eliot McIntire and Alex Chubaty

Examples

```
if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
## This will save the "caribou" object at the save interval of 1 unit of time
## in the outputPath location
  outputPath <- file.path(tempdir(), "test_save")
  times <- list(start = 0, end = 1, "month")

  modules <- list("randomLandscapes", "caribouMovement")
  paths <- list(
    modulePath = getSampleModules(tempdir()),
    outputPath = outputPath
  )
 opts <- options("spades.moduleCodeChecks" = FALSE,
                 "spades.useRequire" = FALSE) # not necessary for example

  ## save multiple outputs
  parameters <- list(
    .globals = list(stackName = "landscape"),
    caribouMovement = list(
      .saveObjects = c("caribou", "habitatQuality"),
      .saveInitialTime = 1, .saveInterval = 1
    ),
    randomLandscapes = list(.plots = NA, nx = 20, ny = 20))

  mySim <- simInit(times = times, params = parameters, modules = modules,
                 paths = paths)

  spades(mySim, .plotInitialTime = NA) # plotting not relevant for this example
  dir(outputPath)
  # remove the files
  file.remove(dir(outputPath, full.names = TRUE))

  options(opts) # clean up
}
```

`saveSimList` *Save a whole* `simList` *object to disk*

Description

Saving a simList may not work using the standard approaches (e.g., save, saveRDS, and qs2::qs_save). There are 2 primary reasons why this doesn't work as expected: the activeBindings that are in place within modules (these allow the mod and Par to exist), and file-backed objects, such as SpatRaster and Raster*. Because of these, a user should use saveSimList and loadSimList. These will save the object and recover the object using the filename supplied, if there are no file-backed objects. If there are file-backed objects, then it will save an archive (default is .tar.gz using the archive package for non-Windows and zip() if using Windows, as there is currently an unidentified bug in archive* on Windows). The user does not need to specify the filename any differently, as the code will search based on the filename without the file extension.

Usage

```
saveSimList(
  sim,
  filename,
  projectPath = getwd(),
  outputs = TRUE,
  inputs = TRUE,
  cache = FALSE,
  envir,
  files = TRUE,
  ...,
  lazy = FALSE
)
```

Arguments

sim	Either a simList or a character string of the name of a simList that can be found in envir. Using a character string will assign that object name to the saved simList, so when it is recovered it will be given that name.
filename	Character string with the path for saving simList to or reading the simList from. Currently, only .rds and .qs2 file types are supported.
projectPath	Should be the "top level" or project path for the simList. Defaults to getwd(). All other paths will be made relative with respect to this if nested within this.
outputs	Logical. If TRUE, all files identified in outputs(sim) will be included in the zip.
inputs	Logical. If TRUE, all files identified in inputs(sim) will be included in the zip.
cache	Logical. Not yet implemented. If TRUE, all files in cachePath(sim) will be included in the archive. Defaults to FALSE as this could be large, and may include many out of date elements. See Details.
envir	If sim is a character string, then this must be provided. It is the environment where the object named sim can be found.
files	Logical. Should all the files in the optional outputs, inputs, cache be saved. If this is TRUE, then the resulting filename will be silently converted to an archive file with the appropriate extension e.g., .zip or .tar.gz. This will automatically be TRUE if any of the outputs, inputs or cache are TRUE. Setting this to

FALSE will turn off the saving of files specified in inputs(sim), outputs(sim) or the cache.

... Additional arguments. See Details.

lazy Logical. If TRUE, the user objects in sim@.xData are saved into a sibling lazy-load DB (a <filename>_xData.rdx/.rdb pair built by tools:::makeLazyLoadDB()) alongside the shell simList file, rather than monolithically. loadSimList() detects this layout automatically and restores the objects via lazyLoad(), materializing each one only on first access. Defaults to FALSE.

Details

There is a family of 2 functions that are mutually useful for saving and loading simList objects and their associated files (e.g., file-backed Raster*, inputs, outputs, cache) saveSimList(), loadSimList().

The sim@.xData$._sim slot (a circular reference used internally during a running simulation) is removed before saving to avoid redundant data. It is not needed for a saved/restored simList.

Additional arguments may be passed via ..., including:

- files: logical indicating whether files should be included in the archive. if FALSE, will override cache, inputs, outputs, setting them to FALSE.
- symlinks: a named list of paths corresponding to symlinks, which will be used to substitute normalized absolute paths of files. Names should correspond to the names in paths(); values should be project-relative paths. E.g., list(cachePath = "cache", inputPath = "inputs", outputPath = "outputs").

Value

Invoked for side effects of saving both a .qs2 (or .rds) file, and a compressed archive (one of .tar.gz if using non-Windows OS or .zip on Windows).

Two ways to use this

1. **Portable – take the simulation with you** Save everything: the objects, the metadata, and the files behind any file-backed objects. Use this to move a simulation to another machine or hand it to someone else.

   ```
   `saveSimList(sim, "mySim.rds", projectPath = projectPath)`

   `projectPath` is the root that everything is stored relative to, so the
   whole thing can be unpacked somewhere else and still resolve. A
   file-backed object is re-rooted on load if it lives under `projectPath`
   or under one of the sim's own paths (`outputPath`, `inputPath`,
   `cachePath`, ...).
   ```

2. **In place – keep the metadata, leave the files alone** Save the information but not the file bundle, on the assumption you still have the paths the run used – above all outputPath(sim).

`saveSimList(sim, "mySim.rds", projectPath = projectPath, files = FALSE)`

Reload it and use `outputs(sim)` to see what the run wrote, then read back whatever you actually need. This is usually the practical choice: a real run writes far too many objects to bundle into an archive.

See Also

loadSimList()

Examples

```
## ---- 1. Portable: take everything with you ----
projectPath <- file.path(tempdir(), "myProject")
outPath <- file.path(projectPath, "outputs")
dir.create(outPath, recursive = TRUE, showWarnings = FALSE)

sim <- simInit(times = list(start = 0, end = 1, timeunit = "year"),
               paths = list(outputPath = outPath))
sim$anObject <- 1:10

saveSimList(sim, file.path(projectPath, "portable.rds"),
            projectPath = projectPath)

## unpack it anywhere -- pass the new location as projectPath
sim2 <- loadSimList(file.path(projectPath, "portable.rds"),
                    projectPath = projectPath)
sim2$anObject

## ---- 2. In place: metadata only, files stay put ----
## `files = FALSE` skips bundling; the run's own files are left where
## they are, and the reloaded simList tells you where to find them
saveSimList(sim, file.path(projectPath, "inPlace.rds"),
            projectPath = projectPath, files = FALSE)

sim3 <- loadSimList(file.path(projectPath, "inPlace.rds"),
                    projectPath = projectPath)
outputPath(sim3)   # where the run wrote its outputs
outputs(sim3)      # the manifest of what it wrote

unlink(projectPath, recursive = TRUE)
```

---

scheduleConditionalEvent

Schedule a conditional simulation event

Description

Adds a new event to the simulation's conditional event queue, updating the simulation object by creating or appending to `sim$._conditionalEvents`. *This is very experimental. Use with caution.*

Usage

```
scheduleConditionalEvent(
  sim,
  condition,
  moduleName,
  eventType,
  eventPriority = .normal(),
  minEventTime = start(sim),
  maxEventTime = end(sim)
)
```

Arguments

sim	A simList simulation object.
condition	A string, call or expression that will be assessed for TRUE after each event in the regular event queue. It can access objects in the simList by using functions of sim, e.g., "sim$age > 1"
moduleName	A character string specifying the module from which to call the event. If missing, it will use currentModule(sim)
eventType	A character string specifying the type of event from within the module.
eventPriority	A numeric specifying the priority of the event. Lower number means higher priority. As a best practice, it is recommended that decimal values are conceptual grouped by their integer values (e.g., 4.0, 4.25, 4.5 are conceptually similar). See priority().
minEventTime	A numeric specifying the time before which the event should not occur, even if the condition is met. Defaults to start(sim)
maxEventTime	A numeric specifying the time after which the event should not occur, even if the condition is met. Defaults to end(sim)

Details

This conditional event queue will be assessed at every single event in the normal event queue. If there are no conditional events, then spades will proceed as normal. As conditional event conditions are found to be true, then it will trigger a call to scheduleEvent(...) with the current time passed to eventTime *and* it will remove the conditional event from the conditional queue. If the user would like the triggered conditional event to occur as the very next event, then a possible strategy would be to set eventPriority of the conditional event to very low or even negative to ensure it gets inserted at the top of the event queue.

Value

Returns the modified simList object, i.e., sim$._conditionalEvents.

Author(s)

Eliot McIntire

References

Matloff, N. (2011). The Art of R Programming (ch. 7.8.3). San Francisco, CA: No Starch Press, Inc. ISBN 978-1-59327-384-2.

See Also

scheduleEvent(), conditionalEvents()

Examples

```
sim <- simInit(times = list(start = 0, end = 2))
condition <- "sim$age > 1" # provide as string
condition <- quote(sim$age > 1) # provide as a call
condition <- expression(sim$age > 1) # provide as an expression
sim <- scheduleConditionalEvent(sim, condition, "firemodule", "burn")
conditionalEvents(sim)
sim <- spades(sim) # no changes to sim$age, i.e., it is absent
events(sim) # nothing scheduled
sim$age <- 2 # change the value
sim <- spades(sim) # Run spades, the condition is now true, so event is
                   #  scheduled at current time
events(sim)        # now scheduled in the normal event queue
```

---

scheduleEvent *Schedule a simulation event*

Description

Adds a new event to the simulation's event queue, updating the simulation object.

Usage

```
scheduleEvent(
  sim,
  eventTime,
  moduleName,
  eventType,
  eventPriority = .pkgEnv$.normalVal,
  .skipChecks = FALSE
)
```

Arguments

sim	A simList simulation object.
eventTime	A numeric specifying the time of the next event.
moduleName	A character string specifying the module from which to call the event. If missing, it will use currentModule(sim)

eventType	A character string specifying the type of event from within the module.
eventPriority	A numeric specifying the priority of the event. Lower number means higher priority. As a best practice, it is recommended that decimal values are conceptual grouped by their integer values (e.g., 4.0, 4.25, 4.5 are conceptually similar). See priority().
.skipChecks	Logical. If TRUE, then internal checks that arguments match expected types are skipped. Should only be used if speed is critical.

Details

Here, we implement a simulation in a more modular fashion so it's easier to add submodules to the simulation. We use S4 classes and methods, and use data.table instead of data.frame to implement the event queue (because it is much faster).

Value

Returns the modified simList object.

Author(s)

Alex Chubaty

References

Matloff, N. (2011). The Art of R Programming (ch. 7.8.3). San Francisco, CA: No Starch Press, Inc. ISBN 978-1-59327-384-2.

See Also

priority(), scheduleConditionalEvent()

Examples

```
sim <- simInit()
sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn") # default priority
sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn", .normal()) # default priority

sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn", .normal()-1) # higher priority
sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn", .normal()+1) # lower priority

sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn", .highest()) # highest priority
sim <- scheduleEvent(sim, time(sim) + 1.0, "fireSpread", "burn", .lowest()) # lowest priority
events(sim) # shows all scheduled , with eventTime and priority
```

show,simList-method *Show an Object*

Description

Show an Object

Usage

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

Arguments

object	simList

Author(s)

Alex Chubaty

simFile *Generate simulation file name*

Description

Assists with saving and retrieving simulations (e.g., with saveSimList and loadSimList).

Usage

```
simFile(name, path, time = NULL, ext = "rds")
```

Arguments

name	Object name (e.g., "mySimOut")
path	Directory location in where the file will be located (e.g., an outputPath).
time	Optional simulation time to use as filename suffix. Default NULL.
ext	The file extension to use (default "rds").

Value

character string giving a file path for a simulation file

simInit *Initialize a new simulation*

Description

Create a new simulation object, the `sim` object (a `simList`). This object is implemented using an `environment` where all objects and functions are placed. Since environments in `R` are pass by reference, "putting" objects in the `sim` object does no actual copy. The `simList` also stores all parameters, and other important simulation information, such as times, paths, modules, and module load order. See more details below.

Usage

```
simInit(
  times,
  params,
  modules,
  objects,
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan = NULL,
  ...
)

## S4 method for signature
## 'list,list,list,list,list,data.frame,data.frame,character'
simInit(
  times,
  params,
  modules,
  objects,
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan = NULL,
  ...
)

## S4 method for signature 'ANY,ANY,ANY,character,ANY,ANY,ANY,ANY'
simInit(
  times,
  params,
  modules,
  objects,
```

```
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan = NULL,
  ...
)

## S4 method for signature 'ANY,ANY,character,ANY,ANY,ANY,ANY,ANY'
simInit(
  times,
  params,
  modules,
  objects,
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan = NULL,
  ...
)

## S4 method for signature 'ANY,ANY,ANY,ANY,ANY,ANY,ANY,ANY'
simInit(
  times,
  params,
  modules,
  objects,
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan = NULL,
  ...
)

simInit2(l)

simInitDefaults()
```

Arguments

`times`	A named list of numeric simulation start and end times (e.g., `times = list(start = 0.0, end = 10.0, timeunit = "year")`), with the final optional element, `timeunit`, overriding the default time unit used in the simulation which is the "smallest time unit" across all modules. See examples.
`params`	A list of lists of the form `list(moduleName=list(param1=value, param2=value))`. See details.

modules — A named list of character strings specifying the names of modules to be loaded for the simulation. Note: the module name should correspond to the R source file from which the module is loaded. Example: a module named "caribou" will be sourced form the file 'caribou.R', located at the specified modulePath(simList) (see below).

objects — (optional) A vector of object names (naming objects that are in the calling environment of the simInit, which is often the .GlobalEnv unless used programmatically. NOTE: this mechanism will fail if object name is in a package dependency), or a named list of data objects to be passed into the simList (more reliable). These objects will be accessible from the simList as a normal list, e.g,. mySim$obj.

paths — An optional named list with up to 4 named elements, modulePath, inputPath, outputPath, and cachePath. See details. NOTE: Experimental feature now allows for multiple modulePaths to be specified in a character vector. The modules will be searched for sequentially in the first modulePath, then if it doesn't find it, in the second etc.

inputs — A data.frame. Can specify from 1 to 6 columns with following column names: objectName (character, required), file (character), fun (character), package (character), interval (numeric), loadTime (numeric). See inputs() and vignette("ii-modules") section about inputs.

outputs — A data.frame. Can specify from 1 to 7 columns with following column names: objectName (character, required), file (character), fun (character), package (character), saveTime (numeric), arguments (list) and eventPriority (numeric). If eventPriority is not set, it defaults to .last(). If eventPriority is set to a low value, e.g., 0, 1, 2 and saveTime is start(sim), it should give "initial conditions".

See outputs() and vignette("ii-modules") section about outputs.

loadOrder — An optional character vector of module names specifying the order in which to load the modules. If not specified, the module load order will be determined automatically.

notOlderThan — A time, as in from Sys.time(). This is passed into the Cache function that wraps .inputObjects. If the module uses the .useCache parameter and it is set to TRUE or ".inputObjects", then the .inputObjects will be cached. Setting notOlderThan = Sys.time() will cause the cached versions of .inputObjects to be refreshed, i.e., rerun.

... — An alternative way to pass objects, i.e., they can just be named arguments rather than in a objects = list(...). It can also be any options that begins with spades, reproducible or Require, i.e., those identified in spadesOptions(), reproducibleOptions() or RequireOptions(). These will be assigned to the equivalent option *during* the simInit and spades calls only, i.e., they will revert after the simInit or spades calls are complete. NOTE: these are not passed to the simList per se, i.e., they are not be available in the simList during either the simInit or spades calls via sim$xxx, though they will be returned to the simList at the end of each of these calls (so that the next call to e.g., spades can see them). For convenience, these can be supplied without their package prefix, e.g., lowMemory can be specified instead of spades.lowMemory. In cases that

share option name (`reproducible.verbose` and `Require.verbose` both exist), passing `verbose = FALSE` will set both. Obviously this may cause unexpected problems if a module is also expecting a value.

`l` A list of arguments to passed to `simInit`.

Details

Calling this `simInit` function does the following::

What	Details
fills `simList` slots	places the arguments `times`, `params`, `modules`, `paths` into equivalently named `simList` slo
sources all module files	places all function definitions in the `simList`, specifically, into a sub-environment of the m
copies objects	from the global environment to the `simList` environment
loads objects	from disk into the `simList`
schedule object loading/copying	Objects can be loaded into the `simList` at any time during a simulation
schedule object saving	Objects can be saved to disk at any arbitrary time during the simulation. If specified here, t
schedules "init" events	from all modules (see `events()`)
assesses module dependencies	via the inputs and outputs identified in their metadata. This gives the order of the `.inputOb`
determines time unit	takes time units of modules and how they fit together
runs `.inputObjects` functions	from every module *in the module order as determined above*

`params` can only contain updates to any parameters that are defined in the metadata of modules. Take the example of a module named, `Fire`, which has a parameter named `.plotInitialTime`. In the metadata of that module, it says `TRUE`. Here we can override that default with: `list(Fire=list(.plotInitialTime=NA)` effectively turning off plotting. Since this is a list of lists, one can override the module defaults for multiple parameters from multiple modules all at once, with say: `list(Fire = list(.plotInitialTime = NA, .plotInterval = 2), caribouModule = list(N = 1000))`.

The `params` list can contain a list (named `.globals`) of named objects e.g., `.globals = list(climateURL = "https:\\something.com")` entry. Any and every module that has a parameter with that name (in this case `climateURL`) will be overridden with this value as passed.

`params` can be used to set the seed for a specific event in a module. This is done using the normal `params` argument, specifying `.seed` as a list where the elements are a numeric for the seed and the name is the event. Since parameters must be specific to a module, this creates a module and event specific seed e.g., `params = list(moduleName = list(.seed = list(init = 123)))` will set the `init` event of module named `moduleName` to 123. The RN stream will be reset to its state prior to the `set.seed` call after the event.

We implement a discrete event simulation in a more modular fashion so it is easier to add modules to the simulation. We use S4 classes and methods, and fast lists to manage the event queue.

`paths` specifies the location of the module source files, the data input files, and the saving output files. If no paths are specified the defaults are as follows:

- `cachePath`: `getOption("reproducible.cachePath")`;
- `inputPath`: `getOption("spades.inputPath")`;
- `modulePath`: `getOption("spades.modulePath")`;
- `outputPath`: `getOption("spades.outputPath")`.

Value

A `simList` simulation object, pre-initialized from values specified in the arguments supplied.

Parsing and Checking Code

The `simInit` function will attempt to find usage of `sim$xxx` or `sim[['xxx']]` on either side of the assignment (`<-`) operator. It will compare these to the module metadata, specifically `inputObjects` for cases where objects or "gotten" from the `simList` and `outputObjects` for cases where objects are assigned to the `simList`.

It will also attempt to find potential, common function name conflicts with things like `scale` and `stack` (both in **base** and **raster**), and `Plot` (in **quickPlot** and some modules).

This code checking is young and may get false positives and false negatives, i.e., miss things. It also takes computational time, which may be undesirable in operational code. To turn off checking (i.e., if there are too many false positives and negatives), set `options(spades.moduleCodeChecks = FALSE)`.

Caching

Using caching with `SpaDES` is vital when building re-usable and reproducible content. Please see the vignette dedicated to this topic.

Note

Since the objects in the `simList` are passed-by-reference, it is useful to create a copy of the initialized `simList` object prior to running the simulation (e.g., `mySimOut <- spades(Copy(mySim))`). This ensures you retain access to the original objects, which would otherwise be overwritten/modified during the simulation.

The user can opt to run a simpler `simInit` call without inputs, outputs, and times. These can be added later with the accessor methods (See example). These are not required for initializing the simulation via `simInit`. All of `modules`, `paths`, `params`, and `objects` are needed for successful initialization.

Author(s)

Alex Chubaty and Eliot McIntire

References

Matloff, N. (2011). The Art of R Programming (ch. 7.8.3). San Francisco, CA: No Starch Press, Inc. ISBN 978-1-59327-384-2.

See Also

`spades()`, `defineModule()` to get help on metadata elements, `times()`, `params()`, `objs()`, `paths()`, `modules()`, `inputs()`, `outputs()`

Examples

```
 # Tests take several seconds
if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
opts <- options("spades.moduleCodeChecks" = FALSE, "spades.useRequire" = FALSE)
if (!interactive()) opts <- append(opts, options("spades.plots" = NA,
                                                 "spades.debug" = FALSE))

mySim <- simInit(
 times = list(start = 0.0, end = 2.0, timeunit = "year"),
 params = list(
   .globals = list(stackName = "landscape", burnStats = "nPixelsBurned")
 ),
 modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
 paths = list(modulePath = getSampleModules(tempdir()))
)
spades(mySim) # shows plotting

# Change more parameters, removing plotting
mySim <- simInit(
 times = list(start = 0.0, end = 2.0, timeunit = "year"),
 params = list(
   .globals = list(stackName = "landscape", burnStats = "nPixelsBurned"),
   fireSpread = list(.plotInitialTime = NA)
 ),
 modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
 paths = list(modulePath = getSampleModules(tempdir()))
)
outSim <- spades(mySim)

# A little more complicated with inputs and outputs
mapPath <- system.file("maps", package = "quickPlot")
mySim <- simInit(
  times = list(start = 0.0, end = 2.0, timeunit = "year"),
  params = list(
    .globals = list(stackName = "landscape", burnStats = "nPixelsBurned")
  ),
  modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
  paths = list(modulePath = getSampleModules(tempdir()),
               outputPath = tempdir()),
  inputs = data.frame(
    files = dir(file.path(mapPath), full.names = TRUE, pattern = "tif")[1:2],
    functions = "rast",
    package = "terra",
    loadTime = 1,
    stringsAsFactors = FALSE),
  outputs = data.frame(
    expand.grid(objectName = c("caribou","landscape"),
    saveTime = 1:2,
    stringsAsFactors = FALSE)))

 # Use accessors for inputs, outputs
```

```
mySim2 <- simInit(
  times = list(start = 0.0, end = 2.0, timeunit = "year"),
  modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
  params = list(
    .globals = list(stackName = "landscape", burnStats = "nPixelsBurned"),
    randomLandscapes = list(nx = 10, ny = 10)
    ),
  paths = list(
    modulePath = getSampleModules(tempdir()),
    outputPath = tempdir()
  )
)

# add by accessor is equivalent
inputs(mySim2) <- data.frame(
    files = dir(file.path(mapPath), full.names = TRUE, pattern = "tif")[1:2],
    functions = "rast",
    package = "terra",
    loadTime = 1,
    stringsAsFactors = FALSE)
outputs(mySim2) <- data.frame(
    expand.grid(objectName = c("caribou", "landscape"),
    saveTime = 1:2,
    stringsAsFactors = FALSE))
all.equal(mySim, mySim2) # TRUE

# Use accessors for times -- does not work as desired because times are
#   adjusted to the input timeunit during simInit
mySim2 <- simInit(
  params = list(
    .globals = list(stackName = "landscape", burnStats = "nPixelsBurned")
  ),
  modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
  paths = list(modulePath = getSampleModules(tempdir()),
               outputPath = tempdir()),
  inputs = data.frame(
    files = dir(file.path(mapPath), full.names = TRUE, pattern = "tif")[1:2],
    functions = "rast",
    package = "terra",
    loadTime = 1,
    stringsAsFactors = FALSE),
  outputs = data.frame(
    expand.grid(objectName = c("caribou","landscape"),
    saveTime = 1:2,
    eventPriority = c(0,10), # eventPriority 0 may give "initial" conditions
    stringsAsFactors = FALSE))
)

# add times by accessor fails all.equal test because "year" was not
#   declared during module loading, so month became the default
times(mySim2) <- list(current = 0, start = 0.0, end = 2.0, timeunit = "year")
all.equal(mySim, mySim2) # fails because time units are all different, so
                         # several parameters that have time units in
```

```
                          # "months" because they were loaded that way
 params(mySim)$fireSpread$.plotInitialTime
 params(mySim2)$fireSpread$.plotInitialTime
 events(mySim) # load event is at time 1 year
 events(mySim2) # load event is at time 1 month, reported in years because of
               #   update to times above
options(opts)

}
```

`simInitAndSpades2` — `simInitAndSpades2` *is a convenience wrapper for* `do.call(simInitAndSpades, listOfArgs)`*, i.e., a user can pass a list of all the arguments.*

Description

These functions are convenience wrappers that may allow for more efficient caching. Passes all arguments to `simInit()`, then passes the created `simList` to `spades()`.

Usage

```
simInitAndSpades2(l)

simInitAndSpades(
  times,
  params,
  modules,
  objects,
  paths,
  inputs,
  outputs,
  loadOrder,
  notOlderThan,
  debug = getOption("spades.debug"),
  progress,
  cache,
  .plots,
  .plotInitialTime,
  .saveInitialTime,
  events,
  ...
)
```

Arguments

l	A list of arguments to passed to simInitAndSpades.
times	A named list of numeric simulation start and end times (e.g., times = list(start = 0.0, end = 10.0, timeunit = "year")), with the final optional element, timeunit, overriding the default time unit used in the simulation which is the "smallest time unit" across all modules. See examples.
params	A list of lists of the form list(moduleName=list(param1=value, param2=value)). See details.
modules	A named list of character strings specifying the names of modules to be loaded for the simulation. Note: the module name should correspond to the R source file from which the module is loaded. Example: a module named "caribou" will be sourced form the file 'caribou.R', located at the specified modulePath(simList) (see below).
objects	(optional) A vector of object names (naming objects that are in the calling environment of the simInit, which is often the .GlobalEnv unless used programmatically. NOTE: this mechanism will fail if object name is in a package dependency), or a named list of data objects to be passed into the simList (more reliable). These objects will be accessible from the simList as a normal list, e.g,. mySim$obj.
paths	An optional named list with up to 4 named elements, modulePath, inputPath, outputPath, and cachePath. See details. NOTE: Experimental feature now allows for multiple modulePaths to be specified in a character vector. The modules will be searched for sequentially in the first modulePath, then if it doesn't find it, in the second etc.
inputs	A data.frame. Can specify from 1 to 6 columns with following column names: objectName (character, required), file (character), fun (character), package (character), interval (numeric), loadTime (numeric). See inputs() and vignette("ii-modules") section about inputs.
outputs	A data.frame. Can specify from 1 to 7 columns with following column names: objectName (character, required), file (character), fun (character), package (character), saveTime (numeric), arguments (list) and eventPriority (numeric). If eventPriority is not set, it defaults to .last(). If eventPriority is set to a low value, e.g., 0, 1, 2 and saveTime is start(sim), it should give "initial conditions". See outputs() and vignette("ii-modules") section about outputs.
loadOrder	An optional character vector of module names specifying the order in which to load the modules. If not specified, the module load order will be determined automatically.
notOlderThan	A time, as in from Sys.time(). This is passed into the Cache function that wraps .inputObjects. If the module uses the .useCache parameter and it is set to TRUE or ".inputObjects", then the .inputObjects will be cached. Setting notOlderThan = Sys.time() will cause the cached versions of .inputObjects to be refreshed, i.e., rerun.
debug	Optional tools for invoking debugging. Supplying a list will invoke the more powerful logging package. See details. Default is to use the value in getOption("spades.debug").

progress — Logical (TRUE or FALSE show a graphical progress bar), character ("graphical", "text") or numeric indicating the number of update intervals to show in a graphical progress bar.

cache — Logical. If TRUE, then the spades call will be cached. This means that if the call is made again with the same simList, then spades will return the return value from the previous run of that exact same simList. Default FALSE. See Details. See also the vignette on caching for examples.

.plots — Character. Sets the parameter of this name in all modules. See Plots() for possible values. The parameter is intended to slowly take over from .plotInitialTime as a mechanism to turn on or off plotting. For backwards compatibility, if .plotInitialTime is not set in this spades call, but this .plots is used, two things will happen: setting this without "screen" will turn off all plotting; setting this with "screen" will trigger plotting for any modules that use this parameter but will have no effect on other modules. To get plotting, therefore, it may be necessary to also set .plotInitialTime = start(sim).

.plotInitialTime — Numeric. Temporarily override the .plotInitialTime parameter for all modules. See Details.

.saveInitialTime — Numeric. Temporarily override the .plotInitialTime parameter for all modules. See Details.

events — A character vector or a named list of character vectors. If specified, the simulations will only do the events indicated here. If a named list, the names must correspond to the modules and the character vectors can be specific events within each of the named modules. With the list form, all unspecified modules will run *all* their events, including internal spades modules, e.g., save, that get invoked with the outputs argument in simInit. However, if NOT a named list internal spades modules' events will not run, if not listed in the character vector. See example.

... — Arguments passed to simInit() and spades()

Value

Same as spades() (a simList) or

See Also

simInit(), spades()

---

simList-class *The* simList *class*

Description

Contains the minimum components of a SpaDES simulation. Various slot accessor methods (i.e., get and set functions) are provided (see 'Accessor Methods' below).

Details

Based on code from chapter 7.8.3 of Matloff (2011): "Discrete event simulation". Here, we implement a discrete event simulation in a more modular fashion so it's easier to add simulation components (i.e., "simulation modules"). We use S4 classes and methods, and use `data.table::data.table()` instead of `data.frame()` to implement the event queue (because it is much more efficient).

Slots

`modules` List of character names specifying which modules to load.

`params` Named list of potentially other lists specifying simulation parameters.

`events` The list of scheduled events (i.e., event queue), which can be converted to a sorted `data.table` with `events(sim)`. See 'Event Lists' for more information.

`current` The current event, as a `data.table`. See 'Event Lists' for more information..

`completed` An environment consisting of completed events, with each object named a character representation of the order of events. This was converted from a previous version which was a list. This was changed because the list became slow as number of events increased. See 'Event Lists' for more information. It is kept as an environment of individual events for speed. The `completed` method converts it to a sorted `data.table`.

`depends` A `.simDeps` list of `.moduleDeps()` objects containing module object dependency information.

`simtimes` List of numerical values describing the simulation start and end times; as well as the current simulation time.

`inputs` a `data.frame` or `data.table` of files and metadata

`outputs` a `data.frame` or `data.table` of files and metadata

`paths` Named list of paths. See `?.paths`. Partial matching is performed.

`.xData` Environment referencing the objects used in the simulation. Several "shortcuts" to accessing objects referenced by this environment are provided, and can be used on the `simList` object directly instead of specifying the `.xData` slot: `$`, `[[`, `ls`, `ls.str`, `objs`. See examples.

`.envir` Deprecated. Please do not use any more.

Accessor Methods

Several slot (and sub-slot) accessor methods are provided for use, and categorized into separate help pages:

`simList-accessors-envir()`	Simulation environment.
`simList-accessors-events()`	Scheduled and completed events.
`simList-accessors-inout()`	Passing data in to / out of simulations.
`simList-accessors-modules()`	Modules loaded and used; module dependencies.
`simList-accessors-objects()`	Accessing objects used in the simulation.
`simList-accessors-params()`	Global and module-specific parameters.
`simList-accessors-paths()`	File paths for modules, inputs, and outputs.
`simList-accessors-times()`	Simulation times.

Event Lists

The main event list is a sorted `data.table` (keyed) on `eventTime`, and `eventPriority`. The completed event list is an ordered list in the exact order that the events were executed. Each event is represented by a `data.table::data.table()` row consisting of:

`eventTime`	The time the event is to occur.
`moduleName`	The module from which the event is taken.
`eventType`	A character string for the programmer-defined event type.
`eventPriority`	The priority given to the event.

Note

The `simList` class extends the `environment`, by adding several slots that provide information about the metadata for a discrete event simulation. The environment slot, if accessed directly is `.xData` and this is where input and output objects from modules are placed. The `simList_()` class is similar, but it extends the `list` class. All other slots are the same. Thus, `simList` is identical to `simList_`, except that the former uses an environment for objects and the latter uses a list. The class `simList_` is only used internally when saving/loading, because saving/loading a list behaves more reliably than saving/loading an environment.

Author(s)

Alex Chubaty and Eliot McIntire

References

Matloff, N. (2011). The Art of R Programming (ch. 7.8.3). San Francisco, CA: No Starch Press, Inc. ISBN 978-1-59327-384-2.

`spades2` — `spades2` *is a convenience wrapper for* `do.call(spades, listOfArgs)`*, i.e., a user can pass a list of all the arguments.*

Description

Here, we implement a simulation in a more modular fashion so it's easier to add submodules to the simulation. We use S4 classes and methods, and use `data.table` instead of `data.frame` to implement the event queue (because it is much faster).

Usage

```
spades2(l)

spades(
  sim,
  debug = getOption("spades.debug"),
```

```
  progress = NA,
  cache,
  .plotInitialTime = NULL,
  .saveInitialTime = NULL,
  notOlderThan = NULL,
  events = NULL,
  .plots = getOption("spades.plots", NULL),
  ...
)

## S4 method for signature 'simList,ANY,ANY,missing'
spades(
  sim,
  debug = getOption("spades.debug"),
  progress = NA,
  cache,
  .plotInitialTime = NULL,
  .saveInitialTime = NULL,
  notOlderThan = NULL,
  events = NULL,
  .plots = getOption("spades.plots", NULL),
  ...
)

## S4 method for signature 'ANY,ANY,ANY,logical'
spades(
  sim,
  debug = getOption("spades.debug"),
  progress = NA,
  cache,
  .plotInitialTime = NULL,
  .saveInitialTime = NULL,
  notOlderThan = NULL,
  events = NULL,
  .plots = getOption("spades.plots", NULL),
  ...
)
```

Arguments

l	A list of arguments to passed to spades.
sim	A simList simulation object, generally produced by simInit.
debug	Optional tools for invoking debugging. Supplying a list will invoke the more powerful logging package. See details. Default is to use the value in getOption("spades.debug").
progress	Logical (TRUE or FALSE show a graphical progress bar), character ("graphical", "text") or numeric indicating the number of update intervals to show in a graphical progress bar.

cache — Logical. If TRUE, then the spades call will be cached. This means that if the call is made again with the same simList, then spades will return the return value from the previous run of that exact same simList. Default FALSE. See Details. See also the vignette on caching for examples.

.plotInitialTime — Numeric. Temporarily override the .plotInitialTime parameter for all modules. See Details.

.saveInitialTime — Numeric. Temporarily override the .plotInitialTime parameter for all modules. See Details.

notOlderThan — Date or time. Passed to reproducible::Cache to update the cache. Default is NULL, meaning don't update the cache. If Sys.time() is provided, then it will force a recache, i.e., remove old value and replace with new value. Ignored if cache is FALSE.

events — A character vector or a named list of character vectors. If specified, the simulations will only do the events indicated here. If a named list, the names must correspond to the modules and the character vectors can be specific events within each of the named modules. With the list form, all unspecified modules will run *all* their events, including internal spades modules, e.g., save, that get invoked with the outputs argument in simInit. However, if NOT a named list internal spades modules' events will not run, if not listed in the character vector. See example.

.plots — Character. Sets the parameter of this name in all modules. See Plots() for possible values. The parameter is intended to slowly take over from .plotInitialTime as a mechanism to turn on or off plotting. For backwards compatibility, if .plotInitialTime is not set in this spades call, but this .plots is used, two things will happen: setting this without "screen" will turn off all plotting; setting this with "screen" will trigger plotting for any modules that use this parameter but will have no effect on other modules. To get plotting, therefore, it may be necessary to also set .plotInitialTime = start(sim).

... — Any. Can be used to make a unique cache identity, such as "replicate = 1". This will be included in the Cache call, so will be unique and thus spades will not use a cached copy as long as anything passed in ... is unique, i.e., not cached previously.

Details

The is the workhorse function in the SpaDES package. It runs simulations by implementing the rules outlined in the simList.

This function gives simple access to two sets of module parameters: .plotInitialTime and with .plotInitialTime. The primary use of these arguments is to temporarily turn off plotting and saving. "Temporary" means that the simList is not changed, so it can be used again with the simList values reinstated. To turn off plotting and saving, use .plotInitialTime = NA or .saveInitialTime = NA. NOTE: if a module did not use .plotInitialTime or .saveInitialTime, then these arguments will not do anything.

Value

Invisibly returns the modified `simList` object.

Caching with SpaDES

There are numerous ways in which Caching can be used within SpaDES. Please see the vignette https://spades-core.predictiveecology.org/articles/iii-cache.html for many examples. Briefly, functions, events, modules, entire spades calls or experiment calls (see https://github.com/PredictiveEcology/SpaDES.experiment) can be cached and mixtures of all of these will work. For functions, simply wrap the call with `Cache`, moving the original function name into the first argument of Cache. For events or modules, set the module `parameters`, `.useCache`, e.g., `simInit(..., parameters = list(myModule = list(.useCache = "init")))`. This can be set to an event name, which will cache that event, or a logical, which will cache *every* event in that module. Event and module caching makes most sense when the event or module only runs once, such as an initialization or data preparation event/module. Caching an entire simulation is actually just a function call to `simInitAndSpades`, for example. So, simply writing `Cache(simInitAndSpades, modules = ...)` will effectively cache a whole simulation. Finally for experiments, it is just like a function call: `Cache(simInitandExperiment, ...)`. The final way Caching can be done is in `experiment` or `spades`, by setting the `cache` argument.

If `cache` is TRUE, this allows for a seamless way to "save" results of a simulation. The user does not have to intentionally do any saving manually. Instead, upon a call to `spades` in which the `simList` is identical, the function will simply return the result that would have come if it had been rerun. Use this with caution, as it will return exactly the result from a previous run, even if there is stochasticity internally. Caching is only based on the input `simList`. See also the vignette on caching for examples.

`debug`

The most powerful way to use debug is to invoke the `logging` R package. To invoke this, `debug` must be a list with up to 3 named elements: `console`, `file`, and `debug`. Each of these list elements must be a list (including empty `list()` for defaults) with the sub-list elements here:

`console`	`level`	The `level`, see below, of information shown
`file`	`append`	Logical. If `TRUE`, the default, then log entries are appended to file, if it exists
	`file`	A filename. Defaults to `log.txt`
	`level`	The `level`, see below, of information shown
`debug`	See possible values below	

`level` can be a number from 0 to 100 or a character string matching one of the values in `logging::loglevels`. These are hierarchical levels of information passed to the console. Set a lower number for more information and a higher number for less information. Errors in code will be shown if `level` is set to `"ERROR"` or `40` or above; warnings in code will be shown if `level` is set to `"WARN"` or `30` or above; normal messages in code will be shown if `level` is set to `"INFO"` or `20` or above. For consistency with base R messaging, if default level is used, then normal messaging via `message` will be shown; this means that `suppressMessages` will work to suppress messaging only when level is set to `"INFO"` or `20`. Some functions in the SpaDES ecosystem may have information at the lower levels, but currently, there are few to none.

debug is specified as a non-list argument to spades or as list(debug = ...), then it can be a logical, a quoted call, a character vector or a numeric scalar (currently 1 or 2) or a list of any of these to get multiple outputs. This will be run at the start of every event. The following options for debug are available. Each of these can also be in a list to get multiple outputs:

TRUE	current(sim) will be printed at the start of each even
a function name (as character string)	If a function, then it will be run on the simList, e.g., '
moduleName (as character string)	All calls to that module will be entered interactively
eventName (as character string)	All calls that have that event name (in any module) wi
c(<moduleName>, <eventName>)	Only the event in that specified module will be entered
Any other R expression expressed as a character string or quoted call	Will be evaluated with access to the simList as sim. I
A numeric scalar, currently 1 or 2 (maybe others)	This will print out alternative forms of event informati

If not specified in the function call, the package option spades.debug is used.

If options("spades.browserOnError" = TRUE) (experimental still) if there is an error, it will attempt to open a browser in the event where the error occurred. You can edit, and then press c to continue or Q to quit, plus all other normal interactive browser tools. c will trigger a reparse and events will continue as scheduled, starting with the one just edited. There may be some unexpected consequences if the simList objects had already been changed before the error occurred.

Note

The debug option is primarily intended to facilitate building simulation models by the user. Will print additional outputs informing the user of updates to the values of various simList slot components. See https://github.com/PredictiveEcology/SpaDES/wiki/Debugging for details.

Author(s)

Alex Chubaty and Eliot McIntire

References

Matloff, N. (2011). The Art of R Programming (ch. 7.8.3). San Francisco, CA: No Starch Press, Inc. ISBN 978-1-59327-384-2.

See Also

SpaDES.core-package(), simInit(), and the caching vignette (very important for reproducibility): https://spades-core.predictiveecology.org/articles/iii-cache.html which uses reproducible::Cache().

vignettes

Examples

```
if (requireNamespace("SpaDES.tools", quietly = TRUE) &&
      packageVersion("SpaDES.tools") > "3.0.0") {
  # some options are not necessary when not interactive
  opts <- options("spades.moduleCodeChecks" = FALSE, "spades.useRequire" = FALSE)
```

```
  if (!interactive()) opts <- append(opts, options("spades.plots" = NA))
  mySim <- simInit(
   times = list(start = 0.0, end = 1.0, timeunit = "year"),
   params = list(
     randomLandscapes = list(nx = 10, ny = 10),
     .globals = list(stackName = "landscape", burnStats = "nPixelsBurned",
                     .plots = NA) # plotting off --> not relevant for example
   ),
   modules = list("randomLandscapes", "fireSpread", "caribouMovement"),
   paths = list(modulePath = getSampleModules(tempdir()))
  )
  spades(mySim)

# Example of `events` misuse: only the .inputObjects runs because "init"
# (an internal event) was not listed, does not run and, therefore, does
# not schedule other events
spades(mySim, events = c(".inputObjects", "burn", "move", "stats"))
completed(mySim)

# Example of correct use of `events`: this adequately narrows down the
# events to be executed by a particular module, without affecting the
# events of other modules or internal events
spades(mySim, events = list(caribouMovement = c(".inputObjects", "init", "move")))
completed(mySim)

  options(opts) # reset options
}
```

---

spadesClasses *Classes defined in SpaDES*

Description

These S4 classes are defined within SpaDES. "dot" classes are not exported and are therefore intended for internal use only.

Simulation classes

simList()	The simList class
.moduleDeps()	Descriptor object for specifying SpaDES module dependencies
.simDeps()	Defines all simulation dependencies for all modules within a SpaDES simulation

Author(s)

Eliot McIntire and Alex Chubaty

See Also

simInit()

---

spadesOptions SpaDES.core *options*

Description

These provide top-level, powerful settings for a comprehensive SpaDES workflow. To see defaults, run spadesOptions(). See Details below.

Usage

```
spadesOptions()
```

Details

Below are options that can be set with options("spades.xxx" = newValue), where xxx is one of the values below, and newValue is a new value to give the option. Sometimes these options can be placed in the user's .Rprofile file so they persist between sessions.

The following options are likely of interest to most users

OPTION	*DEFAULT*
spades.allowInitDuringSimInit	FALS
spades.browserOnError	FALS
reproducible.cachePath	getOption('reproduc
spades.cacheChaining	FALS
spades.debug	TRU
spades.dotInputObjects	TRU
spades.DTthreads	1L
spades.evalPostEvent	NULL
spades.futureEvents	FALS
spades.logPath	Defaults to a subdirectory (logs/) o
spades.inputPath	Default is a temporary directory (typica
spades.loadReqdPkgs	Default is
spades.lowMemory	FALS
spades.memoryUseInterval	FALS
spades.messagingNumCharsModule	21
spades.moduleCodeChecks	FALS
spades.moduleDocument	TRU
spades.modulePath	file.path(tempdir(), "
spades.moduleRepo	"PredictiveEcology/

spades.nCompleted	1000
spades.outputPath	file.path(tempdir(), "
spades.plots	The value of this will passed to .plots within every module; it will thus override all r
spades.recoveryMode	1L
spades.reqdPkgsDontLoad	NULL
spades.saveFileExtensions	NULL
spades.scratchPath	file.path(tempdir(), "
spades.sessionInfo	TRUE
spades.switchPkgNamespaces	Defun
spades.testMemoryLeaks	TRUE
spades.tolerance	.Machine$doub
spades.urlLog	TRUE
spades.useragent	"https://github.com/Pred
spades.useRequire	!tolower(Sys.getenv("SPADES_U

Value

named list of the *default* package options.

`suppliedElsewhere` *Assess whether an object has or will be supplied from elsewhere*

Description

When loading objects into a `simList`, especially during the `simInit` call, and inside the `.inputObjects` functions of modules, it is often useful to know if an object in question will or has been by the user via the `inputs` or `objects` arguments, or by another module's `.inputObjects` while preparing its expected inputs (via `expectsInputs` in metadata), or if it will be supplied by another module during its `"init"` event. In all these cases, it may not be necessary for a given module to load any default value for its `expectsInputs`. This function can be used as a check to determine whether the module needs to proceed in getting and assigning its default value.

Usage

```
suppliedElsewhere(
  object,
  sim,
  where = c("sim", "user", "initEvent"),
  returnWhere = FALSE
)
```

Arguments

`object`	Character vector
`sim`	A `simList` in which to evaluated whether the object is supplied elsewhere

where	Character vector with one to three of "sim", "user", or "initEvent". Default is all three. Partial matching is used. See details.
returnWhere	Logical, default FALSE, whether the vector of length 3 logical should be returned, or a logical of length one

Details

where indicates which of three places to search, either "sim" i.e., the simList, which would be equivalent to is.null(sim\$objName), or "user" which would be supplied by the user in the simInit function call via outputs or inputs (equivalent to (!('defaultColor' \%in\% sim$.userSuppliedObjNames)) or "initEvent", which would test whether a module that gets loaded **before** the present one **will** create it as part of its outputs (i.e., as indicated by createsOutputs in that module's metadata). There is a caveat to this test, however; if that other event also has the object as an expectsInput, then it would fail this test, as it *also* needs it as an input. This final one ("initEvent") does not explicitly test that the object will be created in the "init" event, only that it is in the outputs of that module, and that it is a module that is loaded prior to this one.

Value

logical

Examples

```
mySim <- simInit()
suppliedElsewhere("test", mySim) # FALSE

# supplied in the simList
mySim$test <- 1
suppliedElsewhere("test", mySim) # TRUE
test <- 1

# supplied from user at simInit time -- note, this object would eventually get into the simList
#   but the user supplied values come *after* the module's .inputObjects, so
#   a basic is.null(sim$test) would return TRUE even though the user supplied test
mySim <- simInit(objects = list("test" = test))
suppliedElsewhere("test", mySim) # TRUE


# Example with prepInputs
# Put chunks like this in your .inputObjects
if (!suppliedElsewhere("test", mySim))
  sim$test <- Cache(prepInputs, "raster.tif", "downloadedArchive.zip",
                    destinationPath = dataPath(sim), studyArea = sim$studyArea,
                    rasterToMatch = sim$otherRasterTemplate, overwrite = TRUE)
```

times *Time usage in* SpaDES

Description

Functions for the simtimes slot of a simList object and its elements. To maintain modularity, the behaviour of these functions depends on where they are used. In other words, different modules can have their own timeunit. SpaDES converts these to seconds when running a simulation, but shows the user time in the units of the model as shown with timeunit(sim)

Usage

```
times(x, ...)

## S4 method for signature 'simList'
times(x)

times(x) <- value

## S4 replacement method for signature 'simList'
times(x) <- value

## S3 method for class 'simList'
time(x, unit, ...)

time(x) <- value

## S4 replacement method for signature 'simList'
time(x) <- value

end(x, ...)

## S3 method for class 'simList'
end(x, unit, ...)

end(x) <- value

## S4 replacement method for signature 'simList'
end(x) <- value

start(x, ...)

## S3 method for class 'simList'
start(x, unit = NULL, ...)

start(x) <- value
```

```
## S4 replacement method for signature 'simList'
start(x) <- value

timeunit(x)

## S4 method for signature 'simList'
timeunit(x)

timeunit(x) <- value

## S4 replacement method for signature 'simList'
timeunit(x) <- value

timeunits(x)

## S4 method for signature 'simList'
timeunits(x)

elapsedTime(x, ...)

## S3 method for class 'simList'
elapsedTime(x, byEvent = TRUE, units = "auto", ...)
```

Arguments

x	A simList
...	Additional parameters.
value	A time, given as a numeric, optionally with a unit attribute, but this will be deduced from the model time units or module time units (if used within a module).
unit	Character. One of the time units used in SpaDES.
byEvent	Logical. If TRUE, the elapsed time will be by module and event; FALSE will report only by module. Default is TRUE.
units	character string. Units in which the results are desired. Can be abbreviated.

Details

timeunit will extract the current units of the time used in a simulation (i.e., within a spades call). If it is set within a simInit, e.g., times=list(start=0, end=52, timeunit = "week"), it will set the units for that simulation. By default, a simInit call will use the smallest unit contained within the metadata for the modules being used. If there are parent modules, then the parent module timeunit will be used even if one of its children is a smaller timeunit. If all modules, including parents, are set to NA, timeunit defaults to seconds. If parents are set to NA, then the set of modules defined by that parent module will be given the smallest units of the children.

Currently, available units are "second", "hours", day", "week", "month", and "year" can be used in the metadata of a module.

The user can also define a new unit. The unit name can be anything, but the function definition must be of the form dunitName, e.g., dyear or dfortnight. The unit name is the part without the d and

the function name definition includes the d. This new function, e.g., `dfortnight <- function(x) lubridate::duration(dday(14))` can be placed anywhere in the search path or in a module.

`timeunits` will extract the current units of the time of all modules used in a simulation. This is different from `timeunit` because it is not necessarily associated with a `spades` call.

In many cases, the "simpler" use of each of these functions may be slower computationally. For instance, it is much faster to use `time(sim, "year")` than `time(sim)`. So as a module developer, it is advantageous to write out the longer one, minimizing the looking up that R must do.

Value

Returns or sets the value of the slot from the `simList` object.

Note

These have default behaviour that is based on the calling frame timeunit. When used inside a module, then the time is in the units of the module. If used in an interactive mode, then the time will be in the units of the simulation.

Additional methods are provided to access the current, start, and end times of the simulation:

`time`	Current simulation time.
`start`	Simulation start time.
`end`	Simulation end time.
`timeunit`	Simulation timeunit.
`timeunits`	Module timeunits.
`times`	List of all simulation times (current, start, end, timeunit).

Author(s)

Alex Chubaty and Eliot McIntire

See Also

SpaDES.core-package, specifically the section 1.2.5 on Simulation times; `elapsedTime()`,

Other functions to access elements of a 'simList' object: `.addDepends()`, `checkpointFile()`, `envir()`, `events()`, `globals()`, `inputs()`, `modules()`, `objs()`, `packages()`, `params()`, `paths()`, `progressInterval()`

Examples

```
# Elapsed Time
s1 <- simInit()
s2 <- spades(s1)
elapsedTime(s2)
elapsedTime(s2, units = "mins")
```

updateList *Update elements of a named list with elements of a second named list*

Description

Defunct. Use `utils::modifyList()` (which can not handle NULL) or `Require::modifyList2()` for case with >2 lists and can handle NULL lists.

Usage

```
updateList(x, y)
```

Arguments

x, y	a named list

Value

A named list, with elements sorted by name. The values of matching elements in list `y` replace the values in list `x`.

Author(s)

Alex Chubaty

use_gha *Use GitHub actions for automated module checking*

Description

See corresponding vignette for more information.

Usage

```
use_gha(name, path)
```

Arguments

name	module name
path	module path

Value

Invoked for its side effect of creating new GitHub Actions workflow files.

writeEventInfo *Write simulation event info to file*

Description

Useful for debugging.

Usage

```
writeEventInfo(sim, file = "events.txt", append = FALSE)
```

Arguments

sim	A simList object.
file	Character specifying the file name (default '"events.txt"').
append	Logical indicating whether to append to the file (default FALSE).

Value

Nothing returned. Invoked for its side effect of writing to file.

Author(s)

Alex Chubaty

writeRNGInfo *Write RNG state info to file*

Description

Useful for debugging and ensuring reproducibility.

Usage

```
writeRNGInfo(file = "seed.txt", append = FALSE)
```

Arguments

file	Character specifying the filename (default "seed.txt").
append	Logical indicating whether to append to the file (default FALSE).

Value

Nothing returned. Invoked for its side effect of writing to file.

Author(s)

Alex Chubaty

`zipModule` *Create a zip archive of a module subdirectory*

Description

The most common use of this would be from a "modules" directory, rather than inside a given module.

Usage

```
zipModule(name, path, version, data = FALSE, ...)

## S4 method for signature 'character,character,character'
zipModule(name, path, version, data = FALSE, ...)

## S4 method for signature 'character,missing,character'
zipModule(name, path, version, data = FALSE, ...)

## S4 method for signature 'character,missing,missing'
zipModule(name, path, version, data = FALSE, ...)

## S4 method for signature 'character,character,missing'
zipModule(name, path, version, data = FALSE, ...)
```

Arguments

`name`	Character string giving the module name.
`path`	A file path to a directory containing the module subdirectory.
`version`	The module version.
`data`	Logical. If `TRUE`, then the data subdirectory will be included in the zip. Default is `FALSE`.
`...`	Additional arguments to `zip()`: e.g., add `"-q"` using `flags="-q -r9X"` (the default flags are `"-r9X"`).

Value

NULL (invisibly). Invoked for its side effect of zipping module files.

Author(s)

Eliot McIntire and Alex Chubaty

zipSimList *Zip a* simList *and various files*

Description

zipSimList will save the simList and file-backed Raster* objects, plus, optionally, files identified in outputs(sim) and inputs(sim). This uses Copy under the hood, to not affect the original simList.

These functions have been moved to other packages.

Usage

```
zipSimList(sim, zipfile, ..., outputs = TRUE, inputs = TRUE, cache = FALSE)

experiment(...)

experiment2(...)

POM(...)

simInitAndExperiment(...)

loadPackages(...)
```

Arguments

sim	Either a simList or a character string of the name of a simList that can be found in envir. Using a character string will assign that object name to the saved simList, so when it is recovered it will be given that name.
zipfile	A character string indicating the filename for the zip file. Passed to zip.
...	Unused.
outputs	Logical. If TRUE, all files identified in outputs(sim) will be included in the zip.
inputs	Logical. If TRUE, all files identified in inputs(sim) will be included in the zip.
cache	Logical. Not yet implemented. If TRUE, all files in cachePath(sim) will be included in the archive. Defaults to FALSE as this could be large, and may include many out of date elements. See Details.

Value

These functions are defunct here and are called for their side effect of signalling a deprecation message pointing at the package that now provides them. They return NULL, invisibly.

`[,simList,character,ANY-method`

Extract an intact `simList` *but with subset of objects*

Description

This is copies the non-object components of a `simList` (e.g., events, etc.) then selects only the objects listed in `i` using `Copy(mget(i, envir(sim)))` and adds them to the returned `simList`.

Usage

```
## S4 method for signature 'simList,character,ANY'
x[i, j, ..., drop = TRUE]
```

Arguments

`x`	A `simList`
`i`	A character vector of objects to select.
`j`	Not used.
`...`	Not used.
`drop`	Not used.

Value

The `[` method returns a complete `simList` class with all the slots copied from the original, but only the named objects in `i` are returned.

Author(s)

Eliot McIntire

Examples

```
s <- simInit()
s$a <- 1
s$b <- 2
s$d <- 3
s[c("a", "d")] # a simList with only 2 objects
```

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