

Package ‘CARNIVAL’

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Title A CAusal Reasoning tool for Network Identification (from gene expression data) using Integer VALue programming

Version 2.4.0

Description An upgraded causal reasoning tool from Melas et al in R with updated assignments of TFs' weights from PROGENy scores. Optimization parameters can be freely adjusted and multiple solutions can be obtained and aggregated.

URL <https://github.com/saezlab/CARNIVAL>

BugReports <https://github.com/saezlab/CARNIVAL/issues>

Depends R (>= 4.0)

Imports readr, stringr, lpSolve, igraph, dplyr, rjson, rmarkdown, methods

biocViews Transcriptomics, GeneExpression, Network

License GPL-3

LazyData true

Encoding UTF-8

Suggests knitr, testthat (>= 2.1.0)

VignetteBuilder knitr

RoxygenNote 7.1.1

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checkOptionsValidity *Checks if provided option names are valid.*

Description

Checks if provided option names are valid.

Usage

```
checkOptionsValidity(solver = getSupportedSolvers()$lpSolve, ...)
```

Arguments

| | |
|--------|--|
| solver | one of the solvers available from getSupportedSolvers(). |
| ... | any possible options from the solver's list |

Examples

```
checkOptionsValidity(solver="lpSolve")
```

`defaultCbcSolveCarnivalOptions`
Sets default CARNIVAL options for cbc.

Description

Sets default CARNIVAL options for cbc.

Usage

`defaultCbcSolveCarnivalOptions(...)`

Arguments

... any possible options from the solver's list

Examples

`#defaultCbcSolveCarnivalOptions()`

`defaultCplexCarnivalOptions`
Sets default CARNIVAL options for cplex.

Description

Sets default CARNIVAL options for cplex.

Usage

`defaultCplexCarnivalOptions(...)`

Arguments

... any possible options from the solver's list

defaultCplexSpecificOptions

Sets default options from cplex documentation.

Description

Sets default options from cplex documentation.

Usage

defaultCplexSpecificOptions(...)

Arguments

... any possible options from the solver's list

defaultLpSolveCarnivalOptions

Sets default CARNIVAL options for lpSolve.

Description

Sets default CARNIVAL options for lpSolve.

Usage

defaultLpSolveCarnivalOptions(...)

Arguments

... any possible options from the solver's list

Examples

defaultLpSolveCarnivalOptions()

```
generateLpFileCarnival
      generateLpFileCarnival
```

Description

```
generateLpFileCarnival
```

Usage

```
generateLpFileCarnival(  
  perturbations = NULL,  
  measurements,  
  priorKnowledgeNetwork,  
  weights = NULL,  
  carnivalOptions = defaultLpSolveCarnivalOptions()  
)
```

Arguments

`perturbations` (optional, if inverse CARNIVAL flavour is used further) vector of targets of perturbations.

`measurements` vector of the measurements (i.e. DoRothEA/VIPER normalised enrichment scores)

`priorKnowledgeNetwork`
data frame of the prior knowledge network

`weights` (optional) vector of the additional weights: e.g. PROGENy pathway scores or measured protein activities.

`carnivalOptions`
the list of options for the run. See `defaultLpSolveCarnivalOptions()`, `defaultCplexCarnivalOptions`, `defaultCbcCarnivalOptions`.

Details

Prepares the input data for the run: transforms data into lp file and .Rdata file. These files can be reused to run CARNIVAL without preprocessing step using `runCarnivalFromLp(..)`

Value

paths to .lp file and .RData file that can be used for `runFromLpCarnival()`

Examples

```
load(file = system.file("toy_perturbations_ex1.RData",  
  package="CARNIVAL"))  
load(file = system.file("toy_measurements_ex1.RData",  
  package="CARNIVAL"))
```

```

load(file = system.file("toy_network_ex1.RData",
                        package="CARNIVAL"))

## lpSolve
#res1 = generateLpFileCarnival(perturbations = toy_perturbations_ex1,
#                             measurements = toy_measurements_ex1,
#                             priorKnowledgeNetwork = toy_network_ex1,
#                             carnivalOptions = defaultLpSolveCarnivalOptions())

#res1["lpFile"] ##path to generated lp file
#res1["parsedDataFile"] ##path to data file used during generation

## Examples for cbc and cplex are commented out because these solvers are not part of R environment
## and need to be installed separately
##
## cbc
## res2 = generateLpFileCarnival(perturbations = toy_perturbations_ex1,
##                               measurements = toy_measurements_ex1,
##                               priorKnowledgeNetwork = toy_network_ex1,
##                               carnivalOptions = defaultCbcCarnivalOptions())
##
## res2["lpFile"] ##path to generated lp file
## res2["parsedDataFile"] ##path to data file used during generation
##
## cplex
## res3 = generateLpFileCarnival(perturbations = toy_perturbations_ex1,
##                               measurements = toy_measurements_ex1,
##                               priorKnowledgeNetwork = toy_network_ex1,
##                               carnivalOptions = defaultCplexCarnivalOptions())
##
## res3["lpFile"] ##path to generated lp file
## res3["parsedDataFile"] ##path to data file used during generation

```

getOptionsList

Returns the list of options needed/supported for each solver.

Description

Returns the list of options needed/supported for each solver.

Usage

```
getOptionsList(solver = "", onlyRequired = F)
```

Arguments

| | |
|--------------|--|
| solver | one of the solvers available from getSupportedSolvers() |
| onlyRequired | logic, set to TRUE if you want to obtain only required options for the run |

Value

list of options, solver-dependent

getSupportedSolvers *Returns the list of supported solvers.*

Description

Returns the list of supported solvers.

Usage

```
getSupportedSolvers()
```

Value

list of currently supported solvers.

isInputValidCarnival *Checks validity of all inputs of CARNIVAL*

Description

Checks validity of all inputs of CARNIVAL

Usage

```
isInputValidCarnival(
  perturbations = NULL,
  measurements,
  priorKnowledgeNetwork,
  weights = NULL,
  carnivalOptions = defaultLpSolveCarnivalOptions()
)
```

Arguments

perturbations (optional, if inverse CARNIVAL flavour is used further) vector of targets of perturbations.

measurements vector of the measurements (i.e. DoRothEA/VIPER normalised enrichment scores)

priorKnowledgeNetwork data frame of the prior knowledge network

weights (optional) vector of the additional weights: e.g. PROGENy pathway scores or measured protein activities.

carnivalOptions the list of options for the run. See defaultLpSolveCarnivalOptions(), defaultCplexCarnivalOptions, defaultCbcCarnivalOptions.

Value

TRUE if everything passed the checks.

| | |
|---------------|--|
| parseCplexLog | <i>Parses the cplex log file and reads some basic information.</i> |
|---------------|--|

Description

Parses the cplex log file and reads some basic information.

Usage

```
parseCplexLog(log)
```

Arguments

| | |
|-----|--|
| log | path of log file resulted from a carnival run OR the content of this file read by read_lines . |
|-----|--|

Value

list variable with following fields: - 'convergence' a table that contains information on the convergence of CPLEX - 'n_solutions' number of solutions found - 'objective' objective function value - 'termination_reason': reason of termination

Author(s)

Attila Gabor, 2021

| | |
|-------------|-------------|
| runCARNIVAL | runCARNIVAL |
|-------------|-------------|

Description

runCARNIVAL

Usage

```

runCARNIVAL(
  inputObj = NULL,
  measObj = measObj,
  netObj = netObj,
  weightObj = NULL,
  solverPath = NULL,
  solver = c("lpSolve", "cplex", "cbc"),
  timelimit = 3600,
  mipGAP = 0.05,
  poolrelGAP = 1e-04,
  limitPop = 500,
  poolCap = 100,
  poolIntensity = 4,
  poolReplace = 2,
  alphaWeight = 1,
  betaWeight = 0.2,
  threads = 0,
  cleanTmpFiles = TRUE,
  keepLPFiles = TRUE,
  dir_name = ""
)

```

Arguments

| | |
|------------|--|
| inputObj | Data frame of the list for target of perturbation - optional or default set to NULL to run invCARNIVAL when inputs are not known. |
| measObj | Data frame of the measurement file (i.e. DoRotheA normalised enrichment scores) - always required. |
| netObj | Data frame of the prior knowledge network - always required. |
| weightObj | Data frame of the additional weight (i.e. PROGENy pathway score or measured protein activities) - optional or default set as NULL to run CARNIVAL without weights. |
| solverPath | Path to executable cbc/cplex file - default set to NULL, in which case the solver from lpSolve package is used. |
| solver | Solver to use: lpSolve/cplex/cbc (Default set to lpSolve). |
| timelimit | CPLEX/Cbc parameter: Time limit of CPLEX optimisation in seconds (default set to 3600). |
| mipGAP | CPLEX parameter: the absolute tolerance on the gap between the best integer objective and the objective of the best node remaining. When this difference falls below the value of this parameter, the linear integer optimization is stopped (default set to 0.05) |
| poolrelGAP | CPLEX/Cbc parameter: Allowed relative gap of accepted solution comparing within the pool of accepted solution (default: 0.0001) |
| limitPop | CPLEX parameter: Allowed number of solutions to be generated (default: 500) |

| | |
|---------------|---|
| poolCap | CPLEX parameter: Allowed number of solution to be kept in the pool of solution (default: 100) |
| poolIntensity | CPLEX parameter: Intensity of solution searching (0,1,2,3,4 - default: 4) |
| poolReplace | CPLEX parameter: Replacement strategy of solutions in the pool (0,1,2 - default: 2 = most diversified solutions) |
| alphaWeight | Objective function: weight for mismatch penalty (default: 1 - will only be applied once measurement file only contains discrete values) |
| betaWeight | Objective function: weight for node penalty (default: 0.2) |
| threads | CPLEX parameter: Number of threads to use default: 0 for maximum number possible threads on system |
| cleanTmpFiles | logic (default=TRUE), specifying if the tmp files made by solvers should be cleaned after run. |
| keepLPFiles | logic (default=TRUE), specifying if the LP file should be kept. |
| dir_name | Specify directory name to store results. by default set to NULL |

Details

Run CARNIVAL pipeline using to the user-provided list of inputs or run CARNIVAL built-in examples. The function is from v1.2 of CARNIVAL and is left for backward compatibility.

Value

The function will return a list of results containing: 1. weightedSIF: A table with 4 columns containing the combined network solutions from CARNIVAL. It contains the Source of the interaction (Node1), Sign of the interaction (Sign), the Target of the interaction (Node2) and the weight of the interaction (Weight) which shows how often an interaction appears across all solutions.

2. nodesAttributes: A table with 6 columns containing information about inferred protein activity states and attributes. It contains the Protein IDs (Node); how often this node has taken an activity of 0, 1 and -1 across the solutions (ZeroAct, UpAct, DownAct); the average activities across solutions (AvgAct); and the node attribute (measured, target, inferred).

3. sifAll: A list of separate network solutions.

4. attributesAll: A list of separate inferred node activities in each solution.

5. diagnostics: reports the convergence of optimization and reason of the termination. Only for CPLEX solver.

Author(s)

Enio Gjerga, 2020 <carnival.developers@gmail.com>

Examples

```
load(file = system.file("toy_perturbations_ex1.RData",
                        package="CARNIVAL"))
load(file = system.file("toy_measurements_ex1.RData",
                        package="CARNIVAL"))
load(file = system.file("toy_network_ex1.RData",
```

```

        package="CARNIVAL"))

## lpSolve
#res1 = runCARNIVAL(inputObj = toy_perturbations_ex1,
#                   measObj = toy_measurements_ex1,
#                   netObj = toy_network_ex1,
#                   solver = 'lpSolve')

#res1$weightedSIF ##see @return
#res1$nodesAttributes ## see @return
#res1$sifAll ## see @return
#res1$attributesAll ## see @return

## Examples for cbc and cplex are commented out because these solvers are not part of R environment
## and need to be installed separately
##
## cbc
## res2 = runCARNIVAL(inputObj = toy_perturbations_ex1,
##                   measObj = toy_measurements_ex1,
##                   netObj = toy_network_ex1,
##                   solver = 'cbc')
##
## res2$weightedSIF ##see @return
## res2$nodesAttributes ## see @return
## res2$sifAll ## see @return
## res2$attributesAll ## see @return
##
## cplex
## res3 = runCARNIVAL(inputObj = toy_perturbations_ex1,
##                   measObj = toy_measurements_ex1,
##                   netObj = toy_network_ex1,
##                   solver = 'cplex')
##
## res3$weightedSIF ##see @return
## res3$nodesAttributes ## see @return
## res3$sifAll ## see @return
## res3$attributesAll ## see @return

```

| | |
|-------------------|-------------------|
| runFromLpCarnival | runCarnivalFromLp |
|-------------------|-------------------|

Description

runCarnivalFromLp

Usage

```
runFromLpCarnival(
  lpFile = "",
```

```

    parsedDataFile = "",
    carnivalOptions = defaultLpSolveCarnivalOptions()
  )

```

Arguments

`lpFile` full path to .lp file

`parsedDataFile` full path to preprocessed .RData file

`carnivalOptions` the list of options for the run. See `defaultLpSolveCarnivalOptions()`, `defaultLpSolveCarnivalOptions`, `defaultCbcCarnivalOptions`.

Details

Runs CARNIVAL pipeline with prepared data - lp file and Rdata file containing variables for ILP formulation.

Value

The function will return a list of results containing:

1. `weightedSIF`: A table with 4 columns containing the combined network solutions from CARNIVAL. It contains the Source of the interaction (`Node1`), Sign of the interaction (`Sign`), the Target of the interaction (`Node2`) and the weight of the interaction (`Weight`) which shows how often an interaction appears across all solutions.

2. `nodesAttributes`: A table with 6 columns containing information about inferred protein activity states and attributes. It contains the Protein IDs (`Node`); how often this node has taken an activity of 0, 1 and -1 across the solutions (`ZeroAct`, `UpAct`, `DownAct`); the average activities across solutions (`AvgAct`); and the node attribute (`measured`, `target`, `inferred`).

3. `sifAll`: A list of separate network solutions.

4. `attributesAll`: A list of separate inferred node activities in each solution.

5. `diagnostics`: reports the convergence of optimization and reason of the termination. Only for CPLEX solver.

Author(s)

Enio Gjerga, Olga Ivanova 2020-2021 <carnival.developers@gmail.com>

Examples

```

lpFilePath = system.file("toy_lp_file_ex1.lp",
                          package="CARNIVAL")

parsedDataFilePath = system.file("toy_parsed_data_ex1.RData",
                                 package="CARNIVAL")

## lpSolve
#res1 = runFromLpCarnival(lpFile = lpFilePath,
#                         parsedDataFile = parsedDataFilePath,
#                         carnivalOptions = defaultLpSolveCarnivalOptions())

```

```

#res1$weightedSIF ##see @return
#res1$nodesAttributes ## see @return
#res1$sifAll ## see @return
#res1$attributesAll ## see @return

## Examples for cbc and cplex are commented out because these solvers are not part of R environment
## and need to be installed separately
##
## cbc
## res2 = runFromLpCarnival(lpFile = lpFilePath,
##                          parsedDataFile = parsedDataFilePath,
##                          carnivalOptions = defaultLpCbcCarnivalOptions())
##
## res2$weightedSIF ##see @return
## res2$nodesAttributes ## see @return
## res2$sifAll ## see @return
## res2$attributesAll ## see @return
##
## cplex
## res3 = runFromLpCarnival(lpFile = lpFilePath,
##                          parsedDataFile = parsedDataFilePath,
##                          carnivalOptions = defaultLpCplexCarnivalOptions())
##
## res3$weightedSIF ##see @return
## res3$nodesAttributes ## see @return
## res3$sifAll ## see @return
## res3$attributesAll ## see @return

```

```
runInverseCarnival    runInverseCarnival
```

Description

runInverseCarnival

Usage

```

runInverseCarnival(
  measurements,
  priorKnowledgeNetwork,
  weights = NULL,
  carnivalOptions = defaultLpSolveCarnivalOptions()
)

```

Arguments

measurements vector of the measurements (i.e. DoRothEA/VIPER normalised enrichment scores)

`priorKnowledgeNetwork`
 data frame of the prior knowledge network

`weights`
 (optional) vector of the additional weights: e.g. PROGENy pathway score or measured protein activities.

`carnivalOptions`
 the list of options for the run. See `defaultLpSolveCarnivalOptions()`, `defaultLpSolveCarnivalOptions`, `defaultCbcCarnivalOptions`.

Details

TODO Replace with correct description

Value

The function will return a list of results containing: 1. `weightedSIF`: A table with 4 columns containing the combined network solutions from CARNIVAL. It contains the Source of the interaction (`Node1`), Sign of the interaction (`Sign`), the Target of the interaction (`Node2`) and the weight of the interaction (`Weight`) which shows how often an interaction appears across all solutions.

2. `nodesAttributes`: A table with 6 columns containing information about inferred protein activity states and attributes. It contains the Protein IDs (`Node`); how often this node has taken an activity of 0, 1 and -1 across the solutions (`ZeroAct`, `UpAct`, `DownAct`); the average activities across solutions (`AvgAct`); and the node attribute (`measured`, `target`, `inferred`).

3. `sifAll`: A list of separate network solutions.

4. `attributesAll`: A list of separate inferred node activities in each solution.

5. `diagnostics`: reports the convergence of optimization and reason of the termination. Only for CPLEX solver.

Author(s)

Enio Gjerga, Olga Ivanova 2020-2021 <carnival.developers@gmail.com>

Examples

```
load(file = system.file("toy_measurements_ex1.RData",
                        package="CARNIVAL"))
load(file = system.file("toy_network_ex1.RData",
                        package="CARNIVAL"))

## lpSolve
#res1 = runInverseCarnival(measurements = toy_measurements_ex1,
#                          #          priorKnowledgeNetwork = toy_network_ex1,
#                          #          carnivalOptions = defaultLpSolveCarnivalOptions())

#res1$weightedSIF ##see @return
#res1$nodesAttributes ## see @return
#res1$sifAll ## see @return
#res1$attributesAll ## see @return

## Examples for cbc and cplex are commented out because these solvers are not part of R environment
```

```

## and need to be installed separately
##
## cbc
## res2 = runInverseCarnival(measurements = toy_measurements_ex1,
##                           priorKnowledgeNetwork = toy_network_ex1,
##                           carnivalOptions = defaultCbcCarnivalOptions())
##
## res2$weightedSIF ##see @return
## res2$nodesAttributes ## see @return
## res2$sifAll ## see @return
## res2$attributesAll ## see @return
##
## cplex
## res3 = runVanillaCarnival(measurements = toy_measurements_ex1,
##                           priorKnowledgeNetwork = toy_network_ex1,
##                           carnivalOptions = defaultCplexCarnivalOptions())
##
## res3$weightedSIF ##see @return
## res3$nodesAttributes ## see @return
## res3$sifAll ## see @return
## res3$attributesAll ## see @return

```

```
runVanillaCarnival    runVanillaCarnival
```

Description

runVanillaCarnival

Usage

```

runVanillaCarnival(
  perturbations,
  measurements,
  priorKnowledgeNetwork,
  weights = NULL,
  carnivalOptions = defaultLpSolveCarnivalOptions()
)

```

Arguments

perturbations vector of targets of perturbations.
measurements vector of the measurements (i.e. DoRothEA/VIPER normalised enrichment scores)
priorKnowledgeNetwork
 data frame of the prior knowledge network
weights (optional) vector of the additional weights: e.g. PROGENy pathway score or measured protein activities.

carnivalOptions

the list of options for the run. See defaultLpSolveCarnivalOptions(), defaultLpSolveCarnivalOptions, defaultCbcCarnivalOptions.

Details

Runs full CARNIVAL pipeline, vanilla(classic) flavour.

Value

The function will return a list of results containing: 1. weightedSIF: A table with 4 columns containing the combined network solutions from CARNIVAL. It contains the Source of the interaction (Node1), Sign of the interaction (Sign), the Target of the interaction (Node2) and the weight of the interaction (Weight) which shows how often an interaction appears across all solutions.

2. nodesAttributes: A table with 6 columns containing information about inferred protein activity states and attributes. It contains the Protein IDs (Node); how often this node has taken an activity of 0, 1 and -1 across the solutions (ZeroAct, UpAct, DownAct); the average activities across solutions (AvgAct); and the node attribute (measured, target, inferred).

3. sifAll: A list of separate network solutions.

4. attributesAll: A list of separate inferred node activities in each solution.

5. diagnostics: reports the convergence of optimization and reason of the termination. Only for CPLEX solver.

Author(s)

Enio Gjerga, Olga Ivanova 2020-2021 <carnival.developers@gmail.com>

Examples

```
load(file = system.file("toy_perturbations_ex1.RData",
                        package="CARNIVAL"))
load(file = system.file("toy_measurements_ex1.RData",
                        package="CARNIVAL"))
load(file = system.file("toy_network_ex1.RData",
                        package="CARNIVAL"))

## lpSolve
#res1 = runVanillaCarnival(perturbations = toy_perturbations_ex1,
#                          #
#                          measurements = toy_measurements_ex1,
#                          #
#                          priorKnowledgeNetwork = toy_network_ex1,
#                          #
#                          carnivalOptions = defaultLpSolveCarnivalOptions())

#res1$weightedSIF ##see @return
#res1$nodesAttributes ## see @return
#res1$sifAll ## see @return
#res1$attributesAll ## see @return

## Examples for cbc and cplex are commented out because these solvers are not part of R environment
## and need to be installed separately
##
```

```
## cbc
## res2 = runVanillaCarnival(perturbations = toy_perturbations_ex1,
##                           measurements = toy_measurements_ex1,
##                           priorKnowledgeNetwork = toy_network_ex1,
##                           carnivalOptions = defaultCbcCarnivalOptions())
##
## res2$weightedSIF ##see @return
## res2$nodesAttributes ## see @return
## res2$sifAll ## see @return
## res2$attributesAll ## see @return
##
## cplex
## res3 = runVanillaCarnival(perturbations = toy_perturbations_ex1,
##                           measurements = toy_measurements_ex1,
##                           priorKnowledgeNetwork = toy_network_ex1,
##                           carnivalOptions = defaultCplexCarnivalOptions())
##
## res3$weightedSIF ##see @return
## res3$nodesAttributes ## see @return
## res3$sifAll ## see @return
## res3$attributesAll ## see @return
```

setCarnivalOptions *Sets CARNIVAL options for the solver.*

Description

Sets CARNIVAL options for the solver.

Usage

```
setCarnivalOptions(solver = getSupportedSolvers()$lpSolve, ...)
```

Arguments

| | |
|--------|--|
| solver | one of the solvers available from getSupportedSolvers(). |
| ... | any possible options from the solver's list |

Examples

```
setCarnivalOptions(solver="lpSolve")
```

suggestedCbcSpecificOptions
Suggests cbc specific options.

Description

Suggests cbc specific options.

Usage

suggestedCbcSpecificOptions(...)

Arguments

... any possible options from the solver's list

Examples

suggestedCbcSpecificOptions()

suggestedCplexSpecificOptions
Suggests cplex specific options.s

Description

Suggests cplex specific options.s

Usage

suggestedCplexSpecificOptions(...)

Arguments

... any possible options from the solver's list

Examples

suggestedCplexSpecificOptions()

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