Package 'CoSMic'

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Title COVID-19 spatial microsimulation for Germany

Version 0.11.1.0000

Description A calibration-microsimulation approach to reduce uncertainty for policy decisions on non-pharmacological interventions in the COVID-19 pandemic.
The package implements an age-structured spatial microsimulation model that extends the Susceptible-Exposed-Infectious-Recovered (SEIR) framework. Using an optimization approach based on subnational trends in the number of intensive care patients, it is able to calibrate the model to the ongoing spread of the epidemic and tries to estimate how the NPIs have affected it. Based on these estimates the model can provide national and sub-national forecasts for trends in the number of ICU patients and other indicators under different scenarios regarding NPIs.

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Encoding UTF-8

LazyData true

RoxygenNote 7.1.1

Imports magrittr, dplyr, rlist, data.table, ggplot2, lhs, GA, doRNG, tictoc, grid, gridExtra, pracma, RColorBrewer

Roxygen list(markdown = TRUE)

Suggests knitr, rmarkdown

VignetteBuilder knitr

R topics documented:

`CoSMic-package` *CoSMic: COVID-19 spatial microsimulation for Germany*

Description

A calibration-microsimulation approach to reduce uncertainty for policy decisions on non-pharmacological interventions in the COVID-19 pandemic. The package implements an age-structured spatial microsimulation model that extends the Susceptible-Exposed-Infectious-Recovered (SEIR) framework. Using an optimization approach based on subnational trends in the number of intensive care patients, it is able to calibrate the model to the ongoing spread of the epidemic and tries to estimate how the NPIs have affected it. Based on these estimates the model can provide national and sub-national forecasts for trends in the number of ICU patients and other indicators under different scenarios regarding NPIs.

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attenuate *Helps with delaying and smoothing changes in R0*

Description

The function smoothes numeric vectors either by logistic or linear interpolation.

Usage

```
attenuate(x, steps = 5, type = "logistic")
```

checkpoint.check.reload *Reload a checkpoint.*

Description

The function loads data necessary to do a checkpoint restart and checks them for usability and differences.

Usage

```
checkpoint.check.reload(ep, sp)
```

Arguments

ep	An execution parameter list as decribed in `set.exec.params()`.
sp	A list with static model parameters as described in `set.static.params()`.

CoSMic *Function executing the simulation model.*

Description

Function executing the simulation model.

Usage

```
CoSMic(ep, sp, iol, pspace, sim.struc, op, opt)
```

Arguments

ep	Execution parameter list. Use `set.exec.params()` in order to create a valid layout.
sp	List with static model parameters. Use `set.static.params()` to create a valid layout.
iol	Input data list. Use `load.input()` to load needed fies and `init.connectivity()` in order to create a valid date layout.
pspace	List holding the parameter space with potentially variable model parameters. Use the setter function `set.pspace()` to add parameters.
sim.struc	List with population data. Use `init.spatial.population()` in order to create a valid layout.
op	List with steering parameters for the optimization process. Use `set.optimization.params()` in order to create a valid layout and `init.reference.data()` in order to init the optimization targets based on observed data.
opt	Numeric vector with model parameters subject to optimization.

Value

Depends upon the selected execution procedure given by ep$exec.procedure.

1. In case `ep$exec.procedure="Optimization"` a scalar target value is returned.
2. In case `ep$exec.procedure="Basic-Param"` a list with transient result data is returned.

ToDo

- Capture Error Messages in foreach and model loop
- Fix county plots
- Implement statisitcs output against opt.targets
- Implement normed standard deviation as target value in Global daths & icu_cases & local deaths
- Implement Error message in case R0county contains county id which is not selected for simulation.

`CoSMic.Opt` *Application of the GA algorithm to CoSMic.*

Description

The function applies the GA algorithm to the CoSMic simulation model function. it uses the wrapper function `ff()` as the objective function and `GA.Monitor()` to return intermediate results during the course of the optimization.

Usage

```
CoSMic.Opt(ep, sp, iol, pspace, sim.struc, op, cl)
```

Arguments

ep	Execution parameter list. Use set.exec.params() in order to create a valid layout.
sp	List with static model parameters. Use set.static.params() to create a valid layout.
iol	Input data list. Use load.input() to load needed fies and init.connectivity() in order to create a valid date layout.
pspace	List holding the parameter space with potentially variable model parameters. Use the setter function set.pspace() to add parameters.
sim.struc	List with population data. Use init.spatial.population() in order to create a valid layout.
op	List with steering parameters for the optimization process. Use set.optimization.params() in order to create a valid layout and init.reference.data() in order to init the optimization targets based on observed data.
cl	A parallel cluster prepared by init.parallel.execution().

---

export.csv *Export csv*

Description

The function exports the contents of rr as csv files.

Usage

```
export.csv(rr)
```

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export.to.slaves *Export Variables to slaves*

Description

For convenience this function wraps the exportDoMPI and clusterExport functions from the doMPI and doParallel packages.

Usage

```
export.to.slaves(ep, cl, varlist)
```

Arguments

ep	Execution parameter list. Use set.exec.params() in order to create a valid layout.
cl	A parallel cluster prepared by init.parallel.execution().
varlist	Vector of character strings representing variable names to be exported to cl's workers.

ff *CoSMic model function wrapper*

Description

This function wraps the CoSMic model function so that it can be used in the GA algorithm as the objective function.

Usage

```
ff(x, ep, sp, iol, pspace, sim.struc, op)
```

Arguments

x	Numeric vector with model parameters subject to optimization.
ep	Execution parameter list. Use `set.exec.params()` in order to create a valid layout.
sp	List with static model parameters. Use `set.static.params()` to create a valid layout.
iol	Input data list. Use `load.input()` to load needed fies and `init.connectivity()` in order to create a valid date layout.
pspace	List holding the parameter space with potentially variable model parameters. Use the setter function `set.pspace()` to add parameters.
sim.struc	List with population data. Use `init.spatial.population()` in order to create a valid layout.
op	List with steering parameters for the optimization process. Use `set.optimization.params()` in order to create a valid layout and `init.reference.data()` in order to init the optimization targets based on observed data.

Value

A scalar value calculated according to the settings given in op.

finalize.parallel.execution *Finalize parallel execution execution.*

Description

For convenience this function wraps the `closeCluster` and `stopCluster` functions from the `doMPI` and `doParallel` packages.

Usage

```
finalize.parallel.execution(ep, cl)
```

Arguments

ep	Execution parameter list. Use set.exec.params() in order to create a valid layout.
cl	A parallel cluster prepared by init.parallel.execution().

GA.Monitor *GA algorithm monitoring function*

Description

The function provides intermediate output after each iteration of the GA algorithm.

Usage

```
GA.Monitor(
  obj,
  digits = getOption("digits"),
  sp.int = static.params,
  op.int = opt.params
)
```

Arguments

obj	An object provided by the GA function.
digits	The number of digits provided by getOption("digits").
sp.int	List with static model parameters as created by set.static.params().
op.int	List with steering parameters for the optimization process as created by set.static.params().

---

init.connectivity *Initialize regional connectivity*

Description

The function initializes the regional connectivity matrix according to the requested regions to simulate.

Usage

```
init.connectivity(iol, sp, ss)
```

Arguments

iol	Input data list. Use load.input() to load needed fies and init.connectivity() in order to create a valid date layout.
sp	List with static model parameters. Use set.static.params() to create a valid layout.
ss	List with population data. Use init.spatial.population() in order to create a valid layout.

Value

An input data list with modified `connect_work` and `connect_total` components. See `load.input()` about details on how the input data list has to be strucutred in order to be correctly modified by this function.

`init.lhc` *Prepare parameter space*

Description

The function initializes the data.frame carrying the different sets of model parameters resulting from the parameter variations set in the pspace list.

Usage

```
init.lhc(pspace, sp)
```

Arguments

`pspace`	The parameter list pspace set by repeated calls to `set.pspace()`
`A`	list with static model parameters as described in `set.static.params()`.

Value

A data.frame with dimension [<# different evaluations> x <potentially_variable_model_params>] If all model parameters in pspace are fixed, i.e. not variable dim(lhc) will be [sp$iter x <potentially_variable_model_params>]

`init.parallel.execution`

Initalization of the parallel execution.

Description

The function prepares and initializes the parallel execution of the `CoSMic()` model function on computer clusters in dependence from the requested execution procedure and selected parallel execution method.

Usage

```
init.parallel.execution(ep, sp = NULL, op = NULL)
```

`init.reference.data` *Initialization of reference data.*

Description

The function adds a component to the optimization parameter list passed in as parameter `op`. The added component `opt.target` contains observed data depending which data are provided on input to the function `load.input()`. The function additionally checks whether execution of the optimization procedure is possible based on the selected optimization targets and the provided data.

Usage

```
init.reference.data(iol, op, sp, sim.struc)
```

Arguments

`iol`	Input data list. Use `load.input()` to load needed fies and `init.connectivity()` in order to create a valid date layout.
`op`	List with steering parameters for the optimization process. Use `set.optimization.params()` in order to create a valid layout.
`sp`	List with static model parameters. Use `set.static.params()` to create a valid layout.
`sim.struc`	List with population data. Use `init.spatial.population()` in order to create a valid layout.

Value

The list with steering parameters for the optimization process passed in as parameter `op` with an additional component `opt.target` carying observed data, prepared to be used as target data in the optimization procedure of the `CoSMic()` function.

ToDo

Implement ot[dea.nuts2]

`init.spatial.population`
Initialization of the population and its spatial structure.

Description

The function initializes the population and its spatial structure according to the layout requested by `sp$sim.regions`, i.e. the regions selected either at county or state level to be simulated.

Usage

```
init.spatial.population(iol, sp)
```

Arguments

iol	Input data list. Use load.input() to load needed fies and init.connectivity() in order to create a valid date layout.
sp	List with static model parameters. Use set.static.params() to create a valid layout.

Value

A list with population data. Structured as follows:

```
 sim.struc : List of 3
           $ pop     : data.frame
                     $ dist_id: int
                     $ date   : chr
                     $ sex    : chr
                     $ age_gr : int
                     $ total  : int
           $ counties: int
           $ states  : data.frame
                     $ Code       : int
                     $ inhabitants: int
                     $ Shortcut   : chr
                     $ Name       : chr
```

---

load.input *Loading input data*

Description

Loading input data

Usage

```
load.input(
  data.dir,
  country,
  trans.pr,
  pop.data,
  inf.cases,
  dead.cases,
  connect.total,
  connect.work,
  states,
  counties,
  R0.matrix.inp = NULL,
  dead.cases.by.state,
  dead.cases.by.country,
  icu.cases.by.county,
  icu.cases.by.state,
  icu.cases.by.country,
  lhc.data = NULL
)
```

map.R0effects *Map R0effects from NUTS-1 to NUTS-2*

Description

The function maps R0effects on NUTS-1 i.e. German state level to R0effects on NUTS-2 level

Usage

```
map.R0effects(R0effect.nuts2, R0effect.states, rows = NULL)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
sp	A list with static model parameters as described in set.static.params().

plot.R0effect *Plot R0effects over R0changes*

Description

The function plots timelines of the R0effects per state or NUTS2 region.

Usage

```
## S3 method for class 'R0effect'
plot(R0effect, sp, outfile = NULL, silent = FALSE)
```

plots.by.country *Plot timelines accross the complete country*

Description

The function plots timelines accross the complete country. Either fully aggregated with global.plot = TRUE or aggregated once across the first column of the latin hypercube, across each direct parameter with more than one value and once across the parameter set of the first directv parameter.

Usage

```
plots.by.country(
  outfile,
  sp,
  seed_icu,
  seed_dea,
  iol,
  pspace,
  rr,
  ind.states = NULL,
  global.plot,
  x.min = NULL,
  x.max = NULL,
  relative = FALSE,
  silent = FALSE
)
```

`plots.by.state` *Plot timelines accross each state*

Description

The function plots timelines accross each state, aggregated once across the first column in the latin hypercube, ance across each direct parameter with more than one value and once across the parameter set of the first directv parameter.

Usage

```
plots.by.state(
  outfile,
  sp,
  seed_icu,
  seed_dea,
  iol,
  pspace,
  rr,
  region,
  fix.lim,
  filtered = FALSE,
  fk.cases = rep(1/7, 7),
  Sec.Axis = "RMS",
  fk.sec = rep(1/15, 15),
  sec.text = FALSE,
  ind.states = NULL,
  silent = FALSE,
  relative = FALSE
)
```

save.exec.params *Function to save the current list of execution parameters.*

Description

Function to save the current list of execution parameters.

Usage

```
save.exec.params(ep)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().

save.input *Function to save the current list of loaded input data.*

Description

Function to save the current list of loaded input data.

Usage

```
save.input(ep, iol)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
iol	A list with loaded input data as described in load.input().

save.optimization.params *Function to save the current list of loaded input data.*

Description

Function to save the current list of loaded input data.

Usage

```
save.optimization.params(ep, op)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
op	A list with parameters steering the optimization procedure as described in set.optimization.param

save.pspace — *Function to save the current psapce list.*

Description

Function to save the current psapce list.

Usage

```
save.pspace(ep, pspace)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
pspace	The parameter list pspace.

save.spatial.population — *Function to save the current list of execution parameters.*

Description

Function to save the current list of execution parameters.

Usage

```
save.spatial.population(ep, sim.struc)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
sim.struc	List with population data. Use init.spatial.population() in order to create a valid layout.

save.static.params — *Function to save the current list of satic model parameters.*

Description

Function to save the current list of satic model parameters.

Usage

```
save.static.params(ep, sp)
```

Arguments

ep	An execution parameter list as decribed in set.exec.params().
sp	A list with static model parameters as described in set.static.params().

`set.exec.params` *Setup of execution parameters*

Description

Setup of execution parameters

Usage

```
set.exec.params(
  exec.procedure = "Basic-Param",
  parallel.method = "OMP",
  max.cores = 4,
  omp.cluster.dbg = FALSE,
  data.dir = "Data",
  output.dir = NULL,
  model.version = "12.0",
  export_name = NULL,
  cp.write = FALSE,
  cp.time = 0,
  cp.reload = FALSE,
  cp.dir = NULL
)
```

Arguments

`exec.procedure`	Set the execution procedure. Valid values are "Basic-Param" or "Optimization" *Defaults to:* `"Basic-Param"`.
`parallel.method`	Set the parallelization method. Valid values are "OMP", "MPI" or "PSOCK" *Defaults to:* `"OMP"`.
`max.cores`	Set the maximum number of cores used in case parallel.method = "OMP". *Defaults to:* `4`
`omp.cluster.dbg`	Whether std.out from workers should be captured to a file called cl.out. *Defaults to:* `FALSE`
`data.dir`	Path to the directory from which input files are read. *Defaults to:* `"Data"`
`model.version`	The model version string. *Currently defaults to:* `12.0`
`export_name`	File name addition for output files. *Defaults to:* `<model.version>-<YYYY-MM-DD_hh:mm:ss>`

Value

A list with parameters needed to set up the execution of the CoSMic function. The default structure is:

```
$exec.procedure
[1] "Basic-Param"
$parallel.method
[1] "OMP"
$max.cores
[1] 4
$omp.cluster.dbg
[1] FALSE
$data.dir
[1] "Data"
$model.version
[1] "12.0"
$export_name
[1] "v12.0-2020-11-07_21:53:00"
```

`set.optimization.params` *Setup of optimization parameters*

Description

Setup of optimization parameters

Usage

```
set.optimization.params(
  opt.target.icu,
  opt.target.deaths,
  opt.target.region,
  opt.names,
  opt.lb,
  opt.ub,
  opt.pop.size,
  opt.max.iter,
  use.sug.sol,
  ep,
  sp,
  pspc,
  opt.filter = NULL
)
```

`set.pspace` *Setup of parameters in parameter space*

Description

The function adds an element to the parameter space list pspace

Usage

```
set.pspace(param, values, type = "direct", s.dev = NULL)
```

Arguments

param	The name of the parameter to be set.
values	The values of the parameter to be set.
type	The parameter type. Allowed values are direct or dist. *Defaults to:* direct
s.dev	Deviations of the values in case of parameter type dist. *Defaults to:* NULL

Value

The function operates on the global scope and modifies the parameter list pspace.\

---

set.static.params *Setup of static parameters*

Description

Setup of static parameters

Usage

```
set.static.params(
  pspace,
  seed.in.inner.loop,
  seed.base,
  country,
  restrict,
  sim.regions,
  sam_prop.ps,
  sim_pop,
  ini_infected,
  seed_infections,
  seed_date,
  seed_before,
  time_n = NULL,
  inf_dur,
  cont_dur,
  ill_dur,
  icu_per_day,
  less_contagious,
  R0_force,
  immune_stop,
  import_R0_matrix = FALSE,
  R0change,
  R0county,
  R0delay,
```

```
  R0delay_days,
  R0delay_type,
  endogenous_lockdown,
  lockdown_effect,
  lockdown_connect,
  lockdown_threshold,
  lockdown_days,
  control_age_sex,
  iter = NULL,
  lhc.samples = NULL,
  lhc.reload = FALSE,
  gplots = FALSE,
  cplots = FALSE,
  cplots.states = FALSE,
  cplots.nuts2 = FALSE,
  results = "Reduced",
  sp.states = NULL
)
```

`setup.projection` *Extraploate 0effects beyond determined values*

Description

The function extrapolates R0effects based on different methods.

Usage

```
setup.projection(
  R0effect,
  sp,
  method = "constant-daily",
  base = NULL,
  length = 8,
  length.days = 14
)
```

Arguments

`R0effect`	A data.frame with R0effects per week and region.
`sp`	An object with static CoSMic model parameters.
`method`	Method by which to extrapolate. Supported values are: `"constant-weekly"`: Extrapolates constantly the R0effect of week `base` to the next `length` weeks. `"constant-daily"`: Determines the averaged daily R0effect from the last `length.days` and extraploates it constantly to the next `length` weeks. *Defaults to:* `"constant-weekly"`.
`base`	The week based on which to extrapolate. If not given the last week i.e. dim(R0effect)[1] is used. *Defaults to:* `NULL`.
`length`	Number of week to extrapolate after base. *Defaults to:* `8`.
`length.days`	Number of days to take into account when extraploation based on daily quantities is done. *Defaults to:* `14`.

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