

Package ‘MetaRVM’

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Title Meta-Population Compartmental Model for Respiratory Virus Diseases

Version 2.1.0

Description Simulates respiratory virus epidemics using meta-population compartmental models following Fadikar et. al. (2025) <[doi:10.1109/WSC68292.2025.11338996](https://doi.org/10.1109/WSC68292.2025.11338996)>. 'MetaRVM' implements a stochastic SEIRD (Susceptible-Exposed-Infected-Recovered-Dead) framework with demographic stratification by user provided attributes. It supports complex epidemiological scenarios including asymptomatic and presymptomatic transmission, hospitalization dynamics, vaccination schedules, and time-varying contact patterns via mixing matrices.

URL <https://RESUME-Epi.github.io/MetaRVM/>,
<https://github.com/RESUME-Epi/MetaRVM>

BugReports <https://github.com/RESUME-Epi/MetaRVM/issues>

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format_metarvm_output *Format MetaRVM simulation output*

Description

This function formats raw MetaRVM simulation output by:

1. Converting time steps to calendar dates
2. Adding user-defined demographic attributes from the initialization-derived population meta-data
3. Handling different disease states appropriately:
 - Regular states (S, E, I, etc.): Keep values at integer time points
 - New count states (n_ prefix): Sum pairs to get daily counts

Usage

```
format_metarvm_output(sim_output, config)
```

Arguments

| | |
|------------|---|
| sim_output | data.table containing raw simulation output from meta_sim |
| config | MetaRVMConfig object or config list containing parameters |

Value

data.table with formatted output including calendar dates and demographics

Note

This function is used for formatting the [meta_sim](#) output when [MetaRVM](#) function is called.

`metaRVM`*Run a MetaRVM epidemic simulation*

Description

`metaRVM()` is the high-level entry point for running a MetaRVM metapopulation respiratory virus simulation. It parses the configuration, runs one or more simulation instances (deterministic or stochastic), formats the ODIN/MetaRVM output into a tidy long table with calendar dates and demographic attributes, and returns a `MetaRVMResults` object for downstream analysis and plotting.

Usage

```
metaRVM(config_input)
```

Arguments

`config_input` Configuration specification in one of three forms:

- **Character string:** path to a YAML configuration file.
- **MetaRVMConfig object:** pre-initialized configuration.
- **Named list:** output from `parse_config()` with `return_object = FALSE`.

Details

The configuration input controls:

- **Population structure** (user-defined categories and the initial compartment counts from the initialization file)
- **Disease parameters** (`ts`, `ve`, `de`, `dp`, `da`, `ds`, `dh`, `dr`, `pea`, `psr`, `phr`, `dv`, etc.)
- **Mixing matrices** (weekday/weekend, day/night contact patterns)
- **Vaccination schedule** and immunity waning
- **Simulation settings** (start date, length, number of instances, stochastic vs. deterministic mode, checkpointing)

Internally, `metaRVM()`:

1. Parses the YAML configuration via `parse_config()`.
2. Calls the ODIN-based simulation engine `meta_sim()` for each instance.
3. Uses `format_metarvm_output()` to convert time steps to dates and attach demographic attributes.
4. Wraps the formatted output and metadata in a `MetaRVMResults` object that supports method chaining for subsetting, summarizing, and plotting.

Value

A [MetaRVMResults](#) R6 object with three key components:

\$results A tidy `data.table` with one row per date–subpopulation–disease state–instance combination. Typical columns include:

- `date`: calendar date (`Date`)
- user-defined demographic category columns (if present in the initialization file)
- `disease_state`: compartment or flow label (e.g., S, E, I_symp, H, R, D, n_SE, n_IsympH, etc.)
- `value`: population count or daily flow
- `instance`: simulation instance index (1, 2, ...)

\$config The [MetaRVMConfig](#) object used for the run.

\$run_info A list with metadata such as `n_instances`, `date_range`, `delta_t`, and checkpoint information.

Author(s)

Arindam Fadikar, Charles Macal, Ignacio Martinez-Moyano, Jonathan Ozik

References

Fadikar, A., et al. "Developing and deploying a use-inspired metapopulation modeling framework for detailed tracking of stratified health outcomes"

See Also

[parse_config\(\)](#) for reading YAML configurations, [MetaRVMConfig](#) for configuration management, [MetaRVMResults](#) for analysis and plotting, [meta_sim\(\)](#) for the low-level simulation engine.

Examples

```
options(odin.verbose = FALSE)
example_config <- system.file("extdata", "example_config.yaml",
                             package = "MetaRVM")

# Run a single-instance simulation from a YAML file
results <- metaRVM(example_config)

# Print a high-level summary
results

# Access the tidy results table
head(results$results)

# Summarize and plot hospitalizations and deaths by user-defined categories
results$summarize(
  group_by      = c("age", "zone"),
  disease_states = c("H", "D"),
  stats         = c("median", "quantile"),
```

```
    quantiles      = c(0.25, 0.75)
  )$plot()

# Using a pre-parsed configuration object
cfg <- parse_config(example_config, return_object = TRUE)
results2 <- metaRVM(cfg)
```

MetaRVMCheck *MetaRVM Checkpoint Class*

Description

R6 class to handle MetaRVM checkpoint data. This class is a simplified version of [MetaRVMConfig](#) tailored for storing and accessing simulation checkpoints.

Details

The MetaRVMCheck class is designed to hold the state of a simulation at a specific time point, allowing for continuation or analysis. It stores all necessary parameters and population states.

Super class

[MetaRVM::MetaRVMConfig](#) -> MetaRVMCheck

Public fields

check_data List containing all parsed checkpoint data

Methods

Public methods:

- [MetaRVMCheck\\$new\(\)](#)
- [MetaRVMCheck\\$clone\(\)](#)

Method `new()`: Initialize a new MetaRVMCheck object

Usage:

```
MetaRVMCheck$new(input)
```

Arguments:

input A list containing checkpoint data.

Returns: A new MetaRVMCheck object.

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
MetaRVMCheck$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Author(s)

Arindam Fadikar

MetaRVMConfig

*MetaRVM Configuration Class***Description**

R6 class to handle MetaRVM configuration data with validation and methods. This class encapsulates all configuration parameters needed for MetaRVM simulations, providing methods for parameter access, validation, and introspection.

Details

The MetaRVMConfig class stores parsed configuration data from YAML files and provides structured access to simulation parameters. It automatically validates configuration completeness and provides convenient methods for accessing demographic categories, initialization-derived population metadata, and other simulation settings.

Public fields

config_file Path to the original YAML config file (if applicable)

config_data List containing all parsed configuration parameters

Methods**Public methods:**

- [MetaRVMConfig\\$new\(\)](#)
- [MetaRVMConfig\\$get\(\)](#)
- [MetaRVMConfig\\$get_all\(\)](#)
- [MetaRVMConfig\\$list_parameters\(\)](#)
- [MetaRVMConfig\\$parameter_summary\(\)](#)
- [MetaRVMConfig\\$set\(\)](#)
- [MetaRVMConfig\\$print\(\)](#)
- [MetaRVMConfig\\$get_pop_map\(\)](#)
- [MetaRVMConfig\\$get_category_names\(\)](#)
- [MetaRVMConfig\\$get_category_values\(\)](#)
- [MetaRVMConfig\\$get_all_categories\(\)](#)
- [MetaRVMConfig\\$clone\(\)](#)

Method `new()`: Initialize a new MetaRVMConfig object

Usage:

```
MetaRVMConfig$new(input)
```

Arguments:

input Either a file path (character) or parsed config list

Returns: New MetaRVMConfig object (invisible)

Method `get()`: Get a configuration parameter

Usage:

`MetaRVMConfig$get(param)`

Arguments:

`param` Parameter name

Returns: The requested parameter value

Method `get_all()`: Get all configuration parameters as a list

Usage:

`MetaRVMConfig$get_all()`

Returns: Named list of all configuration parameters

Method `list_parameters()`: List all available parameter names

Usage:

`MetaRVMConfig$list_parameters()`

Returns: Character vector of parameter names

Method `parameter_summary()`: Show summary of parameter types and sizes

Usage:

`MetaRVMConfig$parameter_summary()`

Returns: Data frame with parameter information

Method `set()`: Set a configuration parameter

Usage:

`MetaRVMConfig$set(param, value)`

Arguments:

`param` Character string. Parameter name to set

`value` The value to assign to the parameter

Returns: Self (invisible) for method chaining

Method `print()`: Print summary of configuration

Usage:

`MetaRVMConfig$print()`

Returns: Self (invisible)

Method `get_pop_map()`: Get population mapping data

Usage:

`MetaRVMConfig$get_pop_map()`

Returns: `data.table` containing `population_id` and user-defined demographic category columns

Method `get_category_names()`: Get names of all category columns

Usage:

```
MetaRVMConfig$get_category_names()
```

Details: Category columns are automatically detected from the initialization CSV file. Any column that is not a reserved column (population_id, N, S0, I0, R0, V0, etc.) is treated as a demographic category (e.g., age, zone, income_level, occupation).

Returns: Character vector of category column names, or empty vector if no categories

Examples:

```
\dontrun{
config <- MetaRVMConfig$new("config.yaml")
category_names <- config$get_category_names() # e.g., c("age", "zone", "risk_group")
}
```

Method `get_category_values()`: Get unique values for a specific category

Usage:

```
MetaRVMConfig$get_category_values(category_name)
```

Arguments:

`category_name` Character string specifying the category name

Returns: Character/numeric vector of unique values for the specified category

Examples:

```
\dontrun{
config <- MetaRVMConfig$new("config.yaml")
ages <- config$get_category_values("age") # if age is defined
income_levels <- config$get_category_values("income_level") # if defined
}
```

Method `get_all_categories()`: Get all categories as a named list

Usage:

```
MetaRVMConfig$get_all_categories()
```

Returns: Named list where names are category column names and values are vectors of unique values for each category. Returns empty list if no categories.

Examples:

```
\dontrun{
config <- MetaRVMConfig$new("config.yaml")
all_cats <- config$get_all_categories()
# Returns: list(age = c("0-17", "18-64", "65+"), risk_group = c("low", "high"), ...)
}
```

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
MetaRVMConfig$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Author(s)

Arindam Fadikar

Examples

```

# Initialize from YAML file
example_config <- system.file("extdata", "example_config.yaml", package = "MetaRVM")
config <- MetaRVMConfig$new(example_config)

# Access parameters
config$get("N_pop")
config$get("start_date")

# Get demographic category names (user-defined)
category_names <- config$get_category_names() # e.g., c("age", "zone", "risk_group")

# Get values for specific categories
ages <- config$get_category_values("age")

# Get all categories as a named list
all_categories <- config$get_all_categories()

## -----
## Method `MetaRVMConfig$get_category_names`
## -----

## Not run:
config <- MetaRVMConfig$new("config.yaml")
category_names <- config$get_category_names() # e.g., c("age", "zone", "risk_group")

## End(Not run)

## -----
## Method `MetaRVMConfig$get_category_values`
## -----

## Not run:
config <- MetaRVMConfig$new("config.yaml")
ages <- config$get_category_values("age") # if age is defined
income_levels <- config$get_category_values("income_level") # if defined

## End(Not run)

## -----
## Method `MetaRVMConfig$get_all_categories`
## -----

## Not run:
config <- MetaRVMConfig$new("config.yaml")
all_cats <- config$get_all_categories()
# Returns: list(age = c("0-17", "18-64", "65+"), risk_group = c("low", "high"), ...)

```

```
## End(Not run)
```

| | |
|----------------|------------------------------|
| MetaRVMResults | <i>MetaRVM Results Class</i> |
|----------------|------------------------------|

Description

R6 class to handle MetaRVM simulation results with comprehensive analysis and visualization methods. This class stores formatted simulation results and provides methods for data summarization, subsetting, and visualization with flexible demographic groupings.

Details

The MetaRVMResults class automatically formats raw simulation output upon initialization, converting time steps to calendar dates and adding demographic attributes. It provides methods for flexible data summarization across any user-defined demographic categories, plus method chaining for streamlined analysis workflows.

Public fields

`config` MetaRVMConfig object used to generate these results
`results` data.table containing formatted simulation results
`run_info` List containing run metadata

Methods

Public methods:

- [MetaRVMResults\\$new\(\)](#)
- [MetaRVMResults\\$print\(\)](#)
- [MetaRVMResults\\$plot\(\)](#)
- [MetaRVMResults\\$subset_data\(\)](#)
- [MetaRVMResults\\$summarize\(\)](#)
- [MetaRVMResults\\$clone\(\)](#)

Method `new()`: Initialize a new MetaRVMResults object

Usage:

```
MetaRVMResults$new(
  raw_results,
  config,
  run_info = NULL,
  formatted_results = NULL
)
```

Arguments:

`raw_results` Raw simulation results data.table

config MetaRVMConfig object used for the simulation
 run_info Optional metadata about the run
 formatted_results formatted simulation results data.table
Returns: New MetaRVMResults object (invisible)

Method print(): Print summary of results

Usage:
 MetaRVMResults\$print()
Returns: Self (invisible)

Method plot(): Plot simulation trajectories directly from results

Usage:
 MetaRVMResults\$plot(
 group_by = character(0),
 disease_states = NULL,
 date_range = NULL,
 instances = NULL,
 stats = NULL,
 quantiles = c(0.25, 0.75),
 exclude_p_columns = TRUE,
 ci_level = 0.95,
 theme = theme_minimal(),
 title = NULL
)

Arguments:

group_by Vector of demographic category names to group/facet by
 disease_states Optional disease states to include
 date_range Optional date range for filtering
 instances Optional instance IDs to include
 stats Statistics for summary plotting. If NULL, plots raw trajectories.
 quantiles Quantiles for uncertainty bands when summary plotting
 exclude_p_columns Logical, whether to exclude p_ columns (default: TRUE)
 ci_level Confidence level label used in summary plot title
 theme ggplot2 theme function (default: theme_minimal())
 title Optional custom title

Returns: ggplot object

Method subset_data(): Subset the data based on any combination of parameters

Usage:
 MetaRVMResults\$subset_data(
 ...,
 disease_states = NULL,
 date_range = NULL,
 instances = NULL,
 exclude_p_columns = TRUE
)

Arguments:

... Named arguments for category filters (e.g., `age = c("0-17")`, `income = c("low", "high")`)
`disease_states` Vector of disease states to include (default: all, excludes `p_ columns`)
`date_range` Vector of two dates `start_date`, and `end_date` for filtering (default: all)
`instances` Vector of instance numbers to include (default: all)
`exclude_p_columns` Logical, whether to exclude `p_ columns` (default: TRUE)

Returns: MetaRVMResults object with subset of results

Method `summarize()`: Summarize results across specified demographic characteristics

Usage:

```
MetaRVMResults$summarize(
  group_by,
  disease_states = NULL,
  date_range = NULL,
  stats = c("mean", "median", "sd"),
  quantiles = c(0.25, 0.75),
  exclude_p_columns = TRUE
)
```

Arguments:

`group_by` Vector of demographic category names to group by. Must be valid category names from the configuration (e.g., `c("age", "zone")`, `c("income_level", "occupation")`). Use `config$get_category_names()` to see available categories.
`disease_states` Vector of disease states to include (default: all, excludes `p_ columns`)
`date_range` Optional date range for filtering
`stats` Vector of statistics to calculate: `c("mean", "median", "sd", "min", "max", "sum", "quantile")`. If NULL, returns all instances
`quantiles` Vector of quantiles to calculate if "quantile" is in stats (default: `c(0.25, 0.75)`)
`exclude_p_columns` Logical, whether to exclude `p_ columns` (default: TRUE)

Returns: `data.table` with summarized time series data or all instances if `stats = NULL`

Method `clone()`: The objects of this class are cloneable with this method.

Usage:

```
MetaRVMResults$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

Author(s)

Arindam Fadikar

Examples

```
options(odin.verbose = FALSE)
example_config <- system.file("extdata", "example_config.yaml", package = "MetaRVM")
# Run simulation
```

```
results_obj <- metaRVM(example_config)
# Access formatted results
head(results_obj$results)

# Subset data with multiple filters
subset_data <- results_obj$subset_data(
  age = c("18-64", "65+"),
  disease_states = c("H", "D"),
  date_range = c(as.Date("2024-01-01"), as.Date("2024-02-01"))
)

# Method chaining for analysis and visualization
results_obj$subset_data(disease_states = "H")$summarize(
  group_by = c("age", "zone"),
  stats = c("median", "quantile"),
  quantiles = c(0.25, 0.75)
)$plot()
```

MetaRVMSummary

MetaRVM Summary Class

Description

R6 class for summarized MetaRVM results with plotting capabilities and method chaining support. This class stores summarized simulation data and provides visualization methods that automatically adapt based on the data structure and grouping variables.

Details

The MetaRVMSummary class is designed to work seamlessly with method chaining from MetaRVM-Results. It stores either summary statistics (mean, median, quantiles, etc.) or individual instance data, and provides intelligent plotting methods that automatically determine appropriate visualizations based on the data structure and demographic groupings.

The class supports two data types:

- **Summary data:** Contains aggregated statistics across simulation instances
- **Instance data:** Contains individual trajectory data for each simulation instance

Plotting behavior adapts automatically:

- Single grouping variable: Facets by demographic category, colors by disease state
- Two grouping variables: Grid layout with both demographics as facet dimensions
- Three grouping variables: Grid layout with first two as facets, third as color

Public Fields

data data.table containing summarized results
 config MetaRVMConfig object from original simulation
 type Character string indicating data type ("summary" or "instances")

Public fields

data Summarized data
 config Original MetaRVMConfig object
 type Type of summary ("instances" or "summary")

Methods**Public methods:**

- [MetaRVMSummary\\$new\(\)](#)
- [MetaRVMSummary\\$print\(\)](#)
- [MetaRVMSummary\\$plot\(\)](#)
- [MetaRVMSummary\\$clone\(\)](#)

Method `new()`: Initialize MetaRVMSummary object

Usage:

```
MetaRVMSummary$new(data, config, type)
```

Arguments:

data data.table containing summarized or instance data
 config MetaRVMConfig object from original simulation
 type Character string indicating data type ("summary" or "instances")

Returns: New MetaRVMSummary object (invisible)

Method `print()`: Print summary of the data object

Usage:

```
MetaRVMSummary$print()
```

Returns: Self (invisible)

Method `plot()`: Plot method that shows median with quantile bands

Usage:

```
MetaRVMSummary$plot(ci_level = 0.95, theme = theme_minimal(), title = NULL)
```

Arguments:

ci_level Confidence level for empirical quantiles (default: 0.95). Only used if quantile columns are not pre-specified
 theme ggplot2 theme function (default: theme_minimal())
 title Optional custom plot title

Details: This method creates time series plots with automatic layout adaptation based on grouping variables:

- For summary data: Shows median lines with quantile confidence bands
- Automatically determines faceting strategy based on number of grouping variables
- Uses disease states for color differentiation when appropriate

The method requires specific data structure:

- Summary data must contain 'median_value' and quantile columns (e.g., 'q25', 'q75')
- Instance data must contain 'instance' column for individual trajectory grouping

Returns: ggplot object

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
MetaRVMSummary$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Author(s)

Arindam Fadikar

Examples

```
options(odin.verbose = FALSE)
example_config <- system.file("extdata", "example_config_dist.yaml", package = "MetaRVM")
# Run simulation
results <- metaRVM(example_config)
# Typically created through method chaining
summary_obj <- results$subset_data(disease_states = "H")$summarize(
  group_by = c("age", "zone"),
  stats = c("median", "quantile"),
  quantiles = c(0.25, 0.75)
)

# Direct plotting
summary_obj$plot()

# Plot with custom ggplot theme and confidence level
summary_obj$plot(theme = ggplot2::theme_bw())
```

Description

The core simulation engine that implements a stochastic compartmental SEIRD (Susceptible-Exposed-Infected-Recovered-Dead) model for respiratory virus epidemics across multiple demographic sub-populations. The function compiles and executes an ODIN-based differential equation model with time-varying contact patterns, vaccination dynamics, and complex disease progression pathways.

Usage

```

meta_sim(
  N_pop,
  ts,
  S0,
  I0,
  P0,
  R0,
  H0 = rep(0, N_pop),
  D0 = rep(0, N_pop),
  Ia0 = rep(0, N_pop),
  Ip0 = rep(0, N_pop),
  E0 = rep(0, N_pop),
  V0 = rep(0, N_pop),
  m_weekday_day,
  m_weekday_night,
  m_weekend_day,
  m_weekend_night,
  start_day = 0,
  delta_t,
  vac_mat,
  dv,
  de,
  pea,
  dp,
  da,
  ds,
  psr,
  dh,
  phr,
  dr,
  ve,
  nsteps,
  is.stoch = FALSE,
  seed = NULL,
  do_chk = FALSE,
  chk_time_steps = NULL,
  chk_file_names = NULL
)

```

Arguments

| | |
|-------|---|
| N_pop | Integer. Number of demographic subpopulations in the model |
| ts | Numeric vector or scalar. Transmission rate for symptomatic individuals in susceptible population. If scalar, applied to all subpopulations |
| S0 | Numeric vector of length N_pop. Initial number of susceptible individuals in each subpopulation |

| | |
|-----------------------------|---|
| I_0 | Numeric vector of length N_{pop} . Initial number of symptomatic infected individuals in each subpopulation |
| P_0 | Numeric vector of length N_{pop} . Total population sizes for each subpopulation |
| R_0 | Numeric vector of length N_{pop} . Initial number of recovered individuals in each subpopulation |
| H_0 | Numeric vector of length N_{pop} . Initial number of hospitalized individuals in each subpopulation (default: $\text{rep}(0, N_{pop})$) |
| D_0 | Numeric vector of length N_{pop} . Initial number of deceased individuals in each subpopulation (default: $\text{rep}(0, N_{pop})$) |
| I_{a0} | Numeric vector of length N_{pop} . Initial number of asymptomatic infected individuals in each subpopulation (default: $\text{rep}(0, N_{pop})$) |
| I_{p0} | Numeric vector of length N_{pop} . Initial number of presymptomatic infected individuals in each subpopulation (default: $\text{rep}(0, N_{pop})$) |
| E_0 | Numeric vector of length N_{pop} . Initial number of exposed individuals in each subpopulation (default: $\text{rep}(0, N_{pop})$) |
| V_0 | Numeric vector of length N_{pop} . Initial number of vaccinated individuals in each subpopulation |
| $m_{\text{weekday_day}}$ | Numeric matrix ($N_{pop} \times N_{pop}$). Contact mixing matrix for weekday daytime (6 AM - 6 PM) interactions |
| $m_{\text{weekday_night}}$ | Numeric matrix ($N_{pop} \times N_{pop}$). Contact mixing matrix for weekday nighttime (6 PM - 6 AM) interactions |
| $m_{\text{weekend_day}}$ | Numeric matrix ($N_{pop} \times N_{pop}$). Contact mixing matrix for weekend daytime (6 AM - 6 PM) interactions |
| $m_{\text{weekend_night}}$ | Numeric matrix ($N_{pop} \times N_{pop}$). Contact mixing matrix for weekend nighttime (6 PM - 6 AM) interactions |
| start_day | Start day of the week expressed as an integer value between 0 and 6, 0 being Monday. Default simulation start day is Monday. |
| delta_t | Positive numeric. Discrete time increment in days (typically 0.5) |
| vac_mat | Numeric matrix. Vaccination schedule with dimensions ($n\text{steps} \times (1 + N_{pop})$). First column contains time indices, remaining columns contain vaccination counts for each subpopulation at each time step |
| dv | Numeric vector or scalar. Mean duration (days) in vaccinated state before immunity waning. If scalar, applied to all subpopulations |
| de | Numeric vector or scalar. Mean duration (days) in exposed state. If scalar, applied to all subpopulations |
| pea | Numeric vector or scalar. Proportion of exposed individuals becoming asymptomatic infectious (vs. presymptomatic), values between 0 and 1. If scalar, applied to all subpopulations. If scalar, applied to all subpopulations |
| dp | Numeric vector or scalar. Mean duration (days) in presymptomatic infectious state. If scalar, applied to all subpopulations |

| | |
|----------------|---|
| da | Numeric vector or scalar. Mean duration (days) in asymptomatic infectious state. If scalar, applied to all subpopulations |
| ds | Numeric vector or scalar. Mean duration (days) in symptomatic infectious state. If scalar, applied to all subpopulations |
| psr | Numeric vector or scalar. Proportion of symptomatic individuals recovering directly (vs. hospitalization), values between 0 and 1. If scalar, applied to all subpopulations. If scalar, applied to all subpopulations |
| dh | Numeric vector or scalar. Mean duration (days) in hospitalized state. If scalar, applied to all subpopulations |
| phr | Numeric vector or scalar. Proportion of hospitalized individuals recovering (vs. death). , values between 0 and 1. If scalar, applied to all subpopulations. |
| dr | Numeric vector or scalar. Mean duration (days) of immunity in recovered state. If scalar, applied to all subpopulations |
| ve | Numeric vector or scalar. Vaccine effectiveness (proportion) , values between 0 and 1. If scalar, applied to all subpopulations |
| nsteps | Integer. Total number of discrete time evolution steps in simulation |
| is.stoch | Logical. Whether to run stochastic simulation (TRUE) or deterministic simulation (FALSE). Default: FALSE |
| seed | Integer or NULL. Random seed for reproducibility. Only used when is.stoch = TRUE. Default: NULL |
| do_chk | Logical. Whether to save model checkpoint at simulation end. Default: FALSE |
| chk_time_steps | Integer vector or NULL. Time steps at which to save checkpoints. |
| chk_file_names | List of character vectors or NULL. File names for checkpoints. Each element of the list corresponds to a time step in chk_time_steps. |

Details

The model implements a metapopulation epidemiological framework with the following features:

Compartmental Structure:

- **S**: Susceptible individuals
- **E**: Exposed (incubating) individuals
- **I_presymp**: Presymptomatic infectious individuals
- **I_asymp**: Asymptomatic infectious individuals
- **I_symp**: Symptomatic infectious individuals
- **H**: Hospitalized individuals
- **R**: Recovered individuals
- **D**: Deceased individuals
- **V**: Vaccinated individuals
- **P**: Total living population (excludes deaths)

Disease Progression Pathways:

1. **S** → **E**: Exposure through contact with infectious individuals
2. **E** → **I_asymp/I_presymp**: Progression to infectious states (proportion p_{ea})
3. **I_presymp** → **I_symp**: Development of symptoms
4. **I_asymp** → **R**: Direct recovery from asymptomatic state
5. **I_symp** → **R/H**: Recovery or hospitalization (proportion p_{sr})
6. **H** → **R/D**: Hospital discharge or death (proportion p_{hr})
7. **R** → **S**: Loss of immunity
8. **S** → **V**: Vaccination
9. **V** → **S/E**: Vaccine waning or breakthrough infection

Mixing Patterns: Contact patterns vary by:

- Day of week: Weekday vs. weekend patterns
- Time of day: Day (6 AM - 6 PM) vs. night (6 PM - 6 AM) patterns
- Each pattern specified by $N_{pop} \times N_{pop}$ contact matrix

Force of Infection: Transmission occurs through contact between susceptible/vaccinated individuals and all infectious compartments ($I_{presymp} + I_{asymp} + I_{symp}$), modified by:

- Population-specific transmission rate, t_s
- Time-varying contact patterns
- Vaccine effectiveness for breakthrough infections

Stochastic vs. Deterministic Mode:

- **Deterministic:** Uses exact differential equations
- **Stochastic:** Adds demographic stochasticity via binomial draws

Vaccination Implementation: Vaccination is implemented as time-varying input with:

- Scheduled vaccination counts per time step and subpopulation
- Vaccine effectiveness reducing infection probability
- Waning immunity returning individuals to susceptible state

Value

Returns a data.table with the following structure:

step Integer time step index (0 to nsteps)

time Continuous simulation time ($step \times \delta_t$)

disease_state Character vector of compartment names

population_id Character vector of subpopulation identifiers

value Numeric values representing population counts in each compartment

Available disease states in output:

- Core compartments: S, E, I_presymp, I_asymp, I_symp, H, R, D, V, P
- Derived outputs: I_all (total infectious), cum_V (cumulative vaccinations)
- Transition flows: n_SE, n_EI, n_HR, n_HD, etc. (new infections, hospitalizations, deaths)
- Debug outputs: p_SE, p_VE, I_eff (probabilities and effective populations)

Parameter Scaling

All duration parameters are automatically converted to rates ($1/\text{duration}$). Scalar parameters are automatically expanded to vectors of length N_{pop} . This allows flexible specification of homogeneous or heterogeneous parameters.

Checkpointing

When `do_chk = TRUE`, the function saves a checkpoint file containing:

- Final compartment states for simulation continuation
- All model parameters for reproducibility
- Vaccination schedule data
- Population structure information

Author(s)

Arindam Fadikar, Charles Macal, Ignacio Martinez-Moyano, Jonathan Ozik

References

- ODIN package: <https://mrc-ide.github.io/odin/>
- Fadikar, A., et al. "Developing and deploying a use-inspired metapopulation modeling framework for detailed tracking of stratified health outcomes"

See Also

[metaRVM](#) for high-level simulation interface with configuration files [parse_config](#) for configuration file processing [format_metarvm_output](#) for output formatting with demographics

Examples

```
options(odin.verbose = FALSE)
# Basic deterministic simulation
N_pop <- 2
nsteps <- 400

# Initialize populations
S0 <- rep(1000, N_pop)
I0 <- rep(10, N_pop)
P0 <- S0 + I0
R0 <- rep(0, N_pop)

# Contact matrices (simplified - identity matrices)
contact_matrix <- diag(N_pop)

# Basic vaccination schedule (10% vaccination)
vac_mat <- matrix(0, nrow = nsteps + 1, ncol = N_pop + 1)
vac_mat[, 1] <- 0:nsteps
vac_mat[1, 1 + (1:N_pop)] <- P0 * 0.1
```

```
# Run simulation
results <- meta_sim(
  N_pop = N_pop,
  ts = 0.5,
  S0 = S0,
  I0 = I0,
  P0 = P0,
  R0 = R0,
  m_weekday_day = contact_matrix,
  m_weekday_night = contact_matrix,
  m_weekend_day = contact_matrix,
  m_weekend_night = contact_matrix,
  delta_t = 0.5,
  vac_mat = vac_mat,
  dv = 365,
  de = 3,
  pea = 0.3,
  dp = 2,
  da = 7,
  ds = 7,
  psr = 0.95,
  dh = 10,
  phr = 0.9,
  dr = 180,
  ve = 0.8,
  nsteps = nsteps,
  is.stoch = FALSE
)
```

parse_config

Parse MetaRVM Configuration File

Description

Reads and parses a YAML configuration file for MetaRVM simulations, extracting all necessary parameters for epidemic modeling including population data, disease parameters, mixing matrices, vaccination schedules, and simulation settings.

Usage

```
parse_config(config_file, return_object = FALSE)
```

Arguments

`config_file` Character string. Path to a YAML configuration file containing model parameters and settings.

`return_object` Logical. If TRUE, returns a `MetaRVMConfig` object for method chaining and enhanced functionality. If FALSE (default), returns a named list for backward compatibility.

Details

The function processes a YAML configuration file with the following main sections:

Simulation Configuration:

- `random_seed`: Optional random seed for reproducibility in case of stochastic simulations or stochastic parameters
- `nsim`: Number of simulation instances (default: 1)
- `nrep`: Number of stochastic replicates per parameter set (default: 1)
- `simulation_mode`: Optional simulation mode. Must be one of "deterministic" or "stochastic" (default: "deterministic").
- `start_date`: Simulation start date in MM/DD/YYYY format
- `length`: Simulation length in days
- `checkpoint_dir`: Optional checkpoint directory for saving intermediate results
- `checkpoint_dates`: Optional list of dates to save checkpoints.
- `restore_from`: Optional path to restore simulation from checkpoint

Population Data:

- `initialization`: CSV file with initial population states and optional user-defined category columns. The file must contain columns `population_id`, `N`, `S0`, `I0`, `V0`, `R0`. Any additional columns are treated as demographic categories.
- `vaccination`: CSV file with vaccination schedule over time. The first column must be dates in MM/DD/YYYY format. The rest of the columns must correspond to respective subpopulations in the numeric order of `population_id`.

Mixing Matrices: Contact matrices for different time periods. Each CSV file must have a matrix of order ($N_{pop} \times N_{pop}$), where, N_{pop} is the number of subpopulations. It is assumed that the i -th row and j -th column correspond to i -th and j -th subpopulations.

- `weekday_day`, `weekday_night`: Weekday contact patterns
- `weekend_day`, `weekend_night`: Weekend contact patterns

Disease Parameters: Epidemiological parameters (can be scalars or distributions):

- `ts`: Transmission rate for symptomatic individuals
- `ve`: Vaccine effectiveness
- `de`, `dp`, `da`, `ds`, `dh`, `dr`: Duration parameters for different disease states
- `pea`, `psr`, `phr`: Probability parameters for disease transitions

Sub-population Parameters: `sub_disease_params` allows specification of different parameter values for specific demographic categories (e.g., age groups, races).

The function supports stochastic parameters through distribution specifications with `dist`, `mu`, `sd`, `shape`, `rate`, etc.

Value

If `return_object = FALSE` (default), returns a named list containing:

N_pop Number of population groups

pop_map Data.table with `population_id` and user-defined demographic categories

S_ini, E_ini, I_asymp_ini, I_presymp_ini, I_symp_ini, H_ini, D_ini, P_ini, V_ini, R_ini Initial compartment populations

vac_time_id, vac_counts, vac_mat Vaccination schedule data

m_wd_d, m_wd_n, m_we_d, m_we_n Contact mixing matrices

ts, ve, dv, de, dp, da, ds, dh, dr, pea, psr, phr Disease parameter matrices ($n_{\text{sim}} \times N_{\text{pop}}$)

start_date Simulation start date as Date object

sim_length Simulation length in days

nsim Number of simulation instances

nrep Number of stochastic replicates per parameter set

simulation_mode Simulation mode: "deterministic" or "stochastic"

random_seed Random seed used (if any)

delta_t Time step size (fixed at 0.5)

chk_file_names, chk_time_steps, do_chk Checkpointing configuration

If `return_object = TRUE`, returns a `MetaRVMConfig` object with methods for parameter access and validation.

Parameter Distributions

Disease parameters can be specified as distributions for stochastic modeling:

- **lognormal**: `dist: "lognormal"`, `mu: value`, `sd: value`
- **gamma**: `dist: "gamma"`, `shape: value`, `rate: value`
- **uniform**: `dist: "uniform"`, `min: value`, `max: value`
- **beta**: `dist: "beta"`, `shape1: value`, `shape2: value`
- **gaussian**: `dist: "gaussian"`, `mean: value`, `sd: value`

File Requirements

Population initialization file must contain columns:

- `population_id`: Unique identifier for each population group, natural numbers
- `N`: Total population size of the subpopulation
- `S0, I0, V0, R0`: Initial compartment counts
- Optional user-defined category columns (e.g., `age`, `race`, `zone`, `income_level`, `occupation`)

Vaccination file must contain: `date` (MM/DD/YYYY format) and vaccination counts for each population group

Author(s)

Arindam Fadikar

See Also

[metaRVM](#) for running simulations with parsed configuration [MetaRVMConfig](#) for the configuration object class [process_vac_data](#) for vaccination data processing

Examples

```
options(odin.verbose = FALSE)
example_config <- system.file("extdata", "example_config.yaml", package = "MetaRVM")
# Parse configuration file and return list (backward compatible)
config <- parse_config(example_config)

# Parse and return MetaRVMConfig object for method chaining
config_obj <- parse_config(example_config, return_object = TRUE)

# Access parameters from config object
config_obj$get("N_pop")
config_obj$list_parameters()

# Use with MetaRVM simulation
results <- metaRVM(config_obj)
```

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