

Package ‘CausalLoopAnalytics’

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Type Package

Title Data-Driven Causal Loop and Feedback Network Analysis

Version 1.0.0

Description Provides tools for constructing signed causal-loop models, discovering directed causal relationships from time-series data using Granger-style tests, identifying and classifying reinforcing and balancing feedback loops, quantifying loop strength, assessing loop stability by bootstrap resampling, calculating network centrality and leverage-point scores, comparing causal-loop models, and producing publication-ready base R visualizations and summaries. The package is domain-agnostic and can be used in human medicine, veterinary medicine, agriculture, epidemiology, ecology, public health, and One Health. Methods are based on Granger (1969) <[doi:10.2307/1912791](https://doi.org/10.2307/1912791)> and Efron (1979) <[doi:10.1214/aos/1176344552](https://doi.org/10.1214/aos/1176344552)>.

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BugReports <https://github.com/vinodhpm/CausalLoopAnalytics/issues>

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add_link	<i>Add a directed causal link</i>
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Description

Adds a directed signed link between two variables in a causal-loop diagram.

Usage

```
add_link(model, source, target, polarity = "+", weight = 1)
```

Arguments

model	A cld object.
source	Character string giving the source variable.
target	Character string giving the target variable.
polarity	Link polarity, specified as "+" or "-".
weight	Numeric weight assigned to the link. Defaults to 1.

Value

An updated object of class cld containing the new directed signed link.

Examples

```
model <- create_cld(c("A", "B"))
model <- add_link(model, "A", "B", polarity = "+")
model
```

add_variable	<i>Add a variable to a causal-loop diagram</i>
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Description

Adds a new variable (node) to an existing causal-loop diagram.

Usage

```
add_variable(model, name)
```

Arguments

model	A cld object.
name	Character string giving the variable name.

Value

An updated object of class cld containing the newly added variable.

Examples

```
model <- create_cld()
model <- add_variable(model, "Population")
model
```

causal_matrix	<i>Extract the causal adjacency matrix</i>
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Description

Returns the signed adjacency matrix representing the causal relationships in a causal-loop diagram.

Usage

```
causal_matrix(model)
```

Arguments

model	A cld object.
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Value

A numeric matrix containing the signed causal adjacency matrix. Rows represent source variables and columns represent target variables. Positive and negative entries represent positive and negative causal relationships, respectively, while zero indicates no direct link.

Examples

```
model <- create_cld(c("A", "B"))
model <- add_link(model, "A", "B", polarity = "+", weight = 2)
causal_matrix(model)
```

classify_loops	<i>Classify feedback loops as reinforcing or balancing</i>
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Description

Classify feedback loops as reinforcing or balancing

Usage

```
classify_loops(model, loops = NULL)
```

Arguments

- model A cld object.
- loops Optional output from find_feedback_loops().

Value

A data frame with loop polarity and type.

compare_cld	<i>Compare two causal-loop models</i>
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Description

Compare two causal-loop models

Usage

```
compare_cld(x, y)
```

Arguments

- x, y cld objects.

Value

A structured comparison.

create_cld	<i>Create a causal-loop diagram</i>
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Description

Creates an empty causal-loop diagram or initializes a causal-loop diagram with a specified set of variables.

Usage

```
create_cld(nodes = character())
```

Arguments

nodes Character vector of variable names. Defaults to an empty character vector.

Value

An object of class cld containing the variable names, a signed adjacency matrix, and a data frame describing the causal links.

Examples

```
model <- create_cld(c("A", "B", "C"))
model
```

find_feedback_loops	<i>Find unique directed feedback loops</i>
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Description

Find unique directed feedback loops

Usage

```
find_feedback_loops(
  model,
  max_length = length(model$nodes),
  include_self_loops = FALSE
)
```

Arguments

- model A cld object.
- max_length Maximum loop length; defaults to number of nodes.
- include_self_loops Whether to include one-node loops.

Value

A list of loop variable vectors.

granger_edges	<i>Estimate pairwise Granger-style causal edges</i>
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Description

Estimate pairwise Granger-style causal edges

Usage

```
granger_edges(data, lag = 1, alpha = 0.05)
```

Arguments

- data Numeric time-series data frame/matrix.
- lag Maximum lag (1 by default).
- alpha Significance threshold.

Details

For each ordered pair $X \rightarrow Y$, the function compares a restricted model containing lags of Y with an unrestricted model containing lags of Y and X . The reported polarity is the sign of the sum of coefficients for the added X lags. This is predictive temporal causality, not proof of mechanistic causation.

Value

Edge table with direction, sign, coefficient and p-value.

`identify_leverage_points`*Identify potential leverage points from network and feedback structure*

Description

Identify potential leverage points from network and feedback structure

Usage

```
identify_leverage_points(  
  model,  
  weights = c(centrality = 0.4, loops = 0.3, strength = 0.3)  
)
```

Arguments

<code>model</code>	A cld object.
<code>weights</code>	Optional named weights for centrality, loop participation and loop strength.

Value

Ranked data frame.

`infer_causal_network` *Infer a causal-loop network from time-series data*

Description

Discovers directed temporal relationships using Granger-style tests and constructs a signed causal-loop model from the resulting edges.

Usage

```
infer_causal_network(data, lag = 1, alpha = 0.05)
```

Arguments

<code>data</code>	A numeric data frame or matrix containing time-series variables.
<code>lag</code>	Maximum lag used for the Granger-style test.
<code>alpha</code>	Significance threshold for retaining causal edges.

Details

This function uses predictive temporal relationships to construct a signed causal-loop diagram. A detected Granger-style relationship should not be interpreted as proof of mechanistic causation.

Value

A cld object containing the inferred causal network and causal edge information.

intervention_analysis	<i>Simulate a structural causal intervention by propagating effects through paths</i>
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Description

Simulate a structural causal intervention by propagating effects through paths

Usage

```
intervention_analysis(model, variable, change = 1, steps = length(model$nodes))
```

Arguments

model	A cld object.
variable	Intervention variable.
change	Numeric change applied to the intervention variable.
steps	Number of propagation steps.

Value

Data frame of propagated signed effects.

loop_stability	<i>Bootstrap stability of feedback loops</i>
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Description

Bootstrap stability of feedback loops

Usage

```
loop_stability(model, B = 200, threshold = 0.5, seed = NULL)
```

Arguments

model	A cld object.
B	Number of bootstrap resamples.
threshold	Probability threshold for reporting stable loops.
seed	Optional random seed.

Value

Data frame with loop stability proportions.

loop_strength	<i>Calculate multiplicative feedback-loop strength</i>
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Description

Calculate multiplicative feedback-loop strength

Usage

```
loop_strength(model, loops = NULL)
```

Arguments

model	A cld object.
loops	Optional loops.

Value

Data frame with edge and loop strength.

network_summary	<i>Summarize a signed causal network</i>
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Description

Summarize a signed causal network

Usage

```
network_summary(model)
```

Arguments

model	A cld object.
-------	---------------

Value

Data frame of node-level metrics.

`plot_cld`*Plot a signed causal-loop diagram*

Description

Produces a base R plot of a signed causal-loop diagram. Variables are displayed as nodes and directed causal relationships are displayed as arrows with their corresponding polarity.

Usage

```
plot_cld(  
  model,  
  vertex.cex = 0.85,  
  edge.cex = 0.75,  
  show_weights = FALSE,  
  seed = 1,  
  main = "Causal Loop Diagram"  
)
```

Arguments

<code>model</code>	A cld object.
<code>vertex.cex</code>	Numeric value controlling node text size.
<code>edge.cex</code>	Numeric value controlling edge-label size.
<code>show_weights</code>	Logical; if TRUE, edge weights are displayed together with their polarity.
<code>seed</code>	Integer seed used to obtain a reproducible circular layout.
<code>main</code>	Character string giving the plot title.

Value

A numeric matrix of node coordinates, returned invisibly. Rows correspond to variables in the causal-loop model and the two columns contain the x- and y-coordinates used for plotting. If the model contains no variables, the function returns NULL invisibly.

Examples

```
model <- create_cld(c("A", "B"))  
model <- add_link(model, "A", "B", polarity = "+")  
plot_cld(model)
```

plot_loops	<i>Plot feedback loop strength</i>
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Description

Produces a base R horizontal bar plot summarizing the strength of identified feedback loops.

Usage

```
plot_loops(model, main = "Feedback Loop Strength")
```

Arguments

model	A cld object.
main	Character string giving the plot title.

Value

A data frame containing the identified feedback loops and their classifications and strengths, returned invisibly. The columns include loop, type, strength, and length. If no feedback loops are detected, an empty data frame is returned invisibly.

Examples

```
model <- create_cld(c("A", "B"))
model <- add_link(model, "A", "B", polarity = "+")
model <- add_link(model, "B", "A", polarity = "+")
plot_loops(model)
```

prepare_data	<i>Prepare a numeric time-series data set</i>
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Description

Prepare a numeric time-series data set

Usage

```
prepare_data(data, scale = FALSE)
```

Arguments

data	Data frame or numeric matrix.
scale	Logical; standardize columns.

Value

Numeric matrix with complete rows.

remove_link	<i>Remove a directed causal link</i>
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Description

Removes a directed link between two variables from a causal-loop diagram.

Usage

```
remove_link(model, source, target)
```

Arguments

model	A cld object.
source	Character string giving the source variable.
target	Character string giving the target variable.

Value

An updated object of class cld with the specified directed link removed.

Examples

```
model <- create_cld(c("A", "B"))
model <- add_link(model, "A", "B", polarity = "+")
model <- remove_link(model, "A", "B")
model
```

remove_variable	<i>Remove a variable from a causal-loop diagram</i>
-----------------	---

Description

Removes a variable and all associated links from a causal-loop diagram.

Usage

```
remove_variable(model, name)
```

Arguments

model	A cld object.
name	Character string giving the variable to remove.

Value

An updated object of class cld with the specified variable and its associated links removed.

Examples

```
model <- create_cld(c("A", "B", "C"))
model <- remove_variable(model, "B")
model
```

summary_causal_loop	<i>Summarize a causal-loop model</i>
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Description

Summarize a causal-loop model

Usage

```
summary_causal_loop(model)
```

Arguments

model	A cld object.
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Value

A concise list of model diagnostics.

validate_cld	<i>Validate a causal-loop model</i>
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Description

Checks the structural validity of a causal-loop model and reports structural characteristics such as isolated variables, source-only variables, sink-only variables, self-loops, and links.

Usage

```
validate_cld(model)
```

Arguments

model A cld object.

Value

A list containing validation status and structural summary information. The list contains valid, n_nodes, n_links, isolated, source_only, sink_only, self_loops, and missing_polarity.

Examples

```
model <- create_cld(c("A", "B"))  
model <- add_link(model, "A", "B", polarity = "+")  
validate_cld(model)
```

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