Package ‘fcaR’

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Title Formal Concept Analysis

Version 1.0.4

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Description Provides tools to perform fuzzy formal concept analysis, presented in Wille (1982) <doi:10.1007/978-3-642-01815-2_23> and in Ganter and Obiedkov (2016) <doi:10.1007/978-3-662-49291-8>.
It provides functions to load and save a formal context, extract its concept lattice and implications.
In addition, one can use the implications to compute semantic closures of fuzzy sets and, thus, build recommendation systems.

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Imports stringr, hasseDiagram, RColorBrewer, scales, arules, tictoc, knitr, Matrix, Rcpp, fractional, methods, tikzDevice

Suggests testthat (>= 2.1.0), covr, rmarkdown

Encoding UTF-8

LazyData true

RoxygenNote 7.1.0

URL https://github.com/neuroimaginador/fcaR

BugReports https://github.com/neuroimaginador/fcaR/issues

Depends R (>= 3.1)

LinkingTo Rcpp

VignetteBuilder knitr

NeedsCompilation yes

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R topics documented:

`as_SparseSet` *Convert Named Vector to SparseSet*

Description

Convert Named Vector to SparseSet

Usage

```
as_SparseSet(A)
```

Arguments

A	A named vector or matrix to build a new `SparseSet`.

Value

A `SparseSet` object.

Examples

```
A <- c(a = 0.1, b = 0.2, p = 0.3, q = 0)
as_SparseSet(A)
```

`as_vector` *Convert SparseSet to vector*

Description

Convert SparseSet to vector

Usage

```
as_vector(v)
```

Arguments

v	A `SparseSet` to convert to vector.

Value

A vector.

Examples

```
A <- c(a = 0.1, b = 0.2, p = 0.3, q = 0)
v <- as_SparseSet(A)
A2 <- as_vector(v)
all(A == A2)
```

`cobre32` *Data for Differential Diagnosis for Schizophrenia*

Description

A subset of the COBRE dataset has been retrieved, by querying SchizConnect for 105 patients with neurological and clinical symptoms, collecting also their corresponding diagnosis.

Usage

```
cobre32
```

Format

A matrix with 105 rows and 32 columns. Column names are related to different scales for depression and Schizophrenia:

COSAS_n The *Simpson-Angus Scale*, 7 items to evaluate Parkinsonism-like alterations, related to schizophrenia, in an individual.

FICAL_n The *Calgary Depression Scale for Schizophrenia*, 9 items (attributes) assessing the level of depression in schizophrenia, differentiating between positive and negative aspects of the disease.

SCIDII_n The *Structured Clinical Interview for DSM-III-R Personality Disorders*, with 14 variables related to the presence of signs affecting personality.

dx_ss if `TRUE`, the diagnosis is strict schizophrenia.

dx_other it `TRUE`, the diagnosis is other than schizophrenia, including schizoaffective, bipolar disorder and major depression.

In summary, the dataset consists in the previous 30 attributes related to signs or symptoms, and 2 attributes related to diagnosis (these diagnoses are mutually exclusive, thus only one of them is assigned to each patient). This makes a dataset with 105 objects (patients) and 32 attributes to explore. The symptom attributes are multi-valued.

Thus, according to the specific scales used, all attributes are fuzzy and graded. For a given attribute (symptom), the available grades range from *absent* to *extreme*, with *minimal*, *mild*, *moderate*, *moderate severe* and *severe* in between.

These fuzzy attributes are mapped to values in the interval [0, 1].

Source

Aine, C. J., Bockholt, H. J., Bustillo, J. R., Cañive, J. M., Caprihan, A., Gasparovic, C., ... & Liu, J. (2017). Multimodal neuroimaging in schizophrenia: description and dissemination. Neuroinformatics, 15(4), 343-364. http://schizconnect.org/

`cobre61` *Data for Differential Diagnosis for Schizophrenia*

Description

A subset of the COBRE dataset has been retrieved, by querying SchizConnect for 105 patients with neurological and clinical symptoms, collecting also their corresponding diagnosis.

Usage

```
cobre61
```

Format

A matrix with 105 rows and 61 columns. Column names are related to different scales for depression and Schizophrenia:

COSAS_n The *Simpson-Angus Scale*, 7 items to evaluate Parkinsonism-like alterations, related to schizophrenia, in an individual.

FIPAN_n The *Positive and Negative Syndrome Scale*, a set of 29 attributes measuring different aspects and symptoms in schizophrenia.

FICAL_n The *Calgary Depression Scale for Schizophrenia*, 9 items (attributes) assessing the level of depression in schizophrenia, differentiating between positive and negative aspects of the disease.

SCIDII_n The *Structured Clinical Interview for DSM-III-R Personality Disorders*, with 14 variables related to the presence of signs affecting personality.

dx_ss if `TRUE`, the diagnosis is strict schizophrenia.

dx_other it `TRUE`, the diagnosis is other than schizophrenia, including schizoaffective, bipolar disorder and major depression.

In summary, the dataset consists in the previous 59 attributes related to signs or symptoms, and 2 attributes related to diagnosis (these diagnoses are mutually exclusive, thus only one of them is assigned to each patient). This makes a dataset with 105 objects (patients) and 61 attributes to explore. The symptom attributes are multi-valued.

Thus, according to the specific scales used, all attributes are fuzzy and graded. For a given attribute (symptom), the available grades range from *absent* to *extreme*, with *minimal*, *mild*, *moderate*, *moderate severe* and *severe* in between.

These fuzzy attributes are mapped to values in the interval [0, 1].

Source

Aine, C. J., Bockholt, H. J., Bustillo, J. R., Cañive, J. M., Caprihan, A., Gasparovic, C., ... & Liu, J. (2017). Multimodal neuroimaging in schizophrenia: description and dissemination. Neuroinformatics, 15(4), 343-364. http://schizconnect.org/

`ConceptLattice` *R6 class for a context lattice*

Description

This class implements the data structure and methods for concept lattices.

Methods

Public methods:

- `ConceptLattice$new()`
- `ConceptLattice$size()`

- ConceptLattice$is_empty()
- ConceptLattice$extents()
- ConceptLattice$intents()
- ConceptLattice$plot()
- ConceptLattice$print()
- ConceptLattice$to_latex()
- ConceptLattice$[()
- ConceptLattice$sublattice()
- ConceptLattice$join_irreducibles()
- ConceptLattice$meet_irreducibles()
- ConceptLattice$decompose()
- ConceptLattice$supremum()
- ConceptLattice$infimum()
- ConceptLattice$subconcepts()
- ConceptLattice$superconcepts()
- ConceptLattice$lower_neighbours()
- ConceptLattice$upper_neighbours()
- ConceptLattice$support()
- ConceptLattice$clone()

Method `new()`**:** Create a new `ConceptLattice` object.

Usage:

```
ConceptLattice$new(extents, intents, objects, attributes, I = NULL)
```

Arguments:

`extents` (dgCMatrix) The extents of all concepts

`intents` (dgCMatrix) The intents of all concepts

`objects` (character vector) Names of the objects in the formal context

`attributes` (character vector) Names of the attributes in the formal context

`I` (dgCMatrix) The matrix of the formal context

Returns: A new `ConceptLattice` object.

Method `size()`**:** Size of the Lattice

Usage:

```
ConceptLattice$size()
```

Returns: The number of concepts in the lattice.

Method `is_empty()`**:** Is the lattice empty?

Usage:

```
ConceptLattice$is_empty()
```

Returns: `TRUE` if the lattice has no concepts.

Method `extents()`**:** Concept Extents

Usage:

```
ConceptLattice$extents()
```

Returns: The extents of all concepts, as a `dgCMatrix`.

Method `intents()`: Concept Intents

Usage:

```
ConceptLattice$intents()
```

Returns: The intents of all concepts, as a `dgCMatrix`.

Method `plot()`: Plot the concept lattice

Usage:

```
ConceptLattice$plot(object_names = TRUE, to_latex = FALSE, ...)
```

Arguments:

`object_names` (logical) If `TRUE`, plot object names, otherwise omit them from the diagram.

`to_latex` (logical) If `TRUE`, export the plot as a `tikzpicture` environment that can be included in a `LaTeX` file.

`...` Other parameters to be passed to the `tikzDevice` that renders the lattice in `LaTeX`, or for the figure caption. See `Details`.

Details: Particular parameters that control the size of the `tikz` output are: `width`, `height` (both in inches), and `pointsize` (in points), that should be set to the font size used in the `documentclass` header in the `LaTeX` file where the code is to be inserted.
If a `caption` is provided, the whole `tikz` picture will be wrapped by a `figure` environment and the caption set.

Returns: If `to_latex` is `FALSE`, it returns nothing, just plots the graph of the concept lattice. Otherwise, this function returns the `LaTeX` code to reproduce the concept lattice.

Method `print()`: Print the Concept Lattice

Usage:

```
ConceptLattice$print()
```

Returns: Nothing, just prints the lattice.

Method `to_latex()`: Write in LaTeX

Usage:

```
ConceptLattice$to_latex(print = TRUE, ncols = 1, numbered = TRUE, align = TRUE)
```

Arguments:

`print` (logical) Print to output?

`ncols` (integer) Number of columns of the output.

`numbered` (logical) Number the concepts?

`align` (logical) Align objects and attributes independently?

Returns: The `LaTeX` code to list all concepts.

Method `[()`: Get Concepts by Index

Usage:

`ConceptLattice$[(indices)`

Arguments:

`indices` (numeric or logical vector) The indices of the concepts to return as a list of SparseConcepts. It can be a vector of logicals where `TRUE` elements are to be retained.

Returns: A list of SparseConcepts.

Method `sublattice()`**:** Sublattice

Usage:

`ConceptLattice$sublattice(...)`

Arguments:

`...` See Details.

Details: As argument, one can provide both integer indices or `SparseConcepts`, separated by commas. The corresponding concepts are used to generate a sublattice.

Returns: The generated sublattice as a new `ConceptLattice` object.

Method `join_irreducibles()`**:** Join-irreducible Elements

Usage:

`ConceptLattice$join_irreducibles()`

Returns: The join-irreducible elements in the concept lattice.

Method `meet_irreducibles()`**:** Meet-irreducible Elements

Usage:

`ConceptLattice$meet_irreducibles()`

Returns: The meet-irreducible elements in the concept lattice.

Method `decompose()`**:** Decompose a concept as the supremum of meet-irreducible concepts

Usage:

`ConceptLattice$decompose(C)`

Arguments:

`C` A list of `SparseConcepts`

Returns: A list, each field is the set of meet-irreducible elements whose supremum is the corresponding element in `C`.

Method `supremum()`**:** Supremum of Concepts

Usage:

`ConceptLattice$supremum(...)`

Arguments:

`...` See Details.

Details: As argument, one can provide both integer indices or `SparseConcepts`, separated by commas. The corresponding concepts are used to compute their supremum in the lattice.

Returns: The supremum of the list of concepts.

Method `infimum()`**:** Infimum of Concepts

Usage:

```
ConceptLattice$infimum(...)
```

Arguments:

`...` See Details.

Details: As argument, one can provide both integer indices or `SparseConcepts`, separated by commas. The corresponding concepts are used to compute their infimum in the lattice.

Returns: The infimum of the list of concepts.

Method `subconcepts()`**:** Subconcepts of a Concept

Usage:

```
ConceptLattice$subconcepts(C)
```

Arguments:

`C` (numeric or `SparseConcept`) The concept to which determine all its subconcepts.

Returns: A list with the subconcepts.

Method `superconcepts()`**:** Superconcepts of a Concept

Usage:

```
ConceptLattice$superconcepts(C)
```

Arguments:

`C` (numeric or `SparseConcept`) The concept to which determine all its superconcepts.

Returns: A list with the superconcepts.

Method `lower_neighbours()`**:** Lower Neighbours of a Concept

Usage:

```
ConceptLattice$lower_neighbours(C)
```

Arguments:

`C` (`SparseConcept`) The concept to which find its lower neighbours

Returns: A list with the lower neighbours of `C`.

Method `upper_neighbours()`**:** Upper Neighbours of a Concept

Usage:

```
ConceptLattice$upper_neighbours(C)
```

Arguments:

`C` (`SparseConcept`) The concept to which find its upper neighbours

Returns: A list with the upper neighbours of `C`.

Method `support()`**:** Get support of each concept

Usage:

```
ConceptLattice$support()
```

Returns: A vector with the support of each concept.

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

Usage:

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

Arguments:

`deep` Whether to make a deep clone.

Examples

```
# Build a formal context
fc_planets <- FormalContext$new(planets)

# Find the concepts
fc_planets$find_concepts()

# Plot the concept lattice
fc_planets$concepts$plot()

# Find join- and meet- irreducible elements
fc_planets$concepts$join_irreducibles()
fc_planets$concepts$meet_irreducibles()

# Get concept support
fc_planets$concepts$support()
```

`fcaR` *fcaR: Tools for Formal Concept Analysis*

Description

The aim of this package is to provide tools to perform fuzzy formal concept analysis (FCA) from within R. It provides functions to load and save a Formal Context, extract its concept lattice and implications. In addition, one can use the implications to compute semantic closures of fuzzy sets and, thus, build recommendation systems.

Details

The fcaR package provides data structures which allow the user to work seamlessly with formal contexts and sets of implications. More explicitly, three main classes are implemented, using the `R6` object-oriented-programming paradigm in R:

- `FormalContext` encapsulates the definition of a formal context (G, M, I), being G the set of objects, M the set of attributes and I the (fuzzy) relationship matrix, and provides methods to operate on the context using FCA tools.
- `ImplicationSet` represents a set of implications over a specific formal context.
- `ConceptLattice` represents the set of concepts and their relationships, including methods to operate on the lattice.

Two additional helper classes are implemented:

- `SparseSet` is a class solely used for visualization purposes, since it encapsulates in sparse format a (fuzzy) set.
- `SparseConcept` encapsulates internally both extent and intent of a formal concept as `SparseSet`. Since fcaR is an extension of the data model in the arules package, most of the methods and classes implemented interoperates with the main `S4` classes in arules (`transactions` and `rules`).

References

Guigues J, Duquenne V (1986). “Familles minimales d’implications informatives résultant d’un tableau de données binaires.” *Mathématiques et Sciences humaines*, *95*, 5-18.

Ganter B, Wille R (1999). *Formal concept analysis : mathematical foundations*. Springer. ISBN 3540627715.

Cordero P, Enciso M, Mora Á, Pérez de Guzman I (2002). “SLFD Logic: Elimination of Data Redundancy in Knowledge Representation.” *Advances in Artificial Intelligence - IBERAMIA 2002*, *2527*, 141-150. doi: 10.1007/3-540-36131-6_15 (URL: http://doi.org/10.1007/3-540-36131-6_15).

Belohlavek R (2002). “Algorithms for fuzzy concept lattices.” In *Proc. Fourth Int. Conf. on Recent Advances in Soft Computing*. Nottingham, United Kingdom, 200-205.

Hahsler M, Grun B, Hornik K (2005). “arules - a computational environment for mining association rules and frequent item sets.” *J Stat Softw*, *14*, 1-25.

Mora A, Cordero P, Enciso M, Fortes I, Aguilera G (2012). “Closure via functional dependence simplification.” *International Journal of Computer Mathematics*, *89*(4), 510-526. Belohlavek R, Cordero P, Enciso M, Mora Á, Vychodil V (2016). “Automated prover for attribute dependencies in data with grades.” *International Journal of Approximate Reasoning*, *70*, 51-67.

Examples

```
# Build a formal context
fc_planets <- FormalContext$new(planets)

# Find its concepts and implications
fc_planets$find_implications()

# Plot the concept lattice
fc_planets$concepts$plot()

# Print the extracted implications
fc_planets$implications
```

FormalContext *R6 class for a formal context*

Description

This class implements the data structure and methods for formal contexts.

Public fields

- `I`: the table for the formal context.
- `attributes`: name of the attributes in the formal context.
- `objects`: name of the objects in the context.
- `grades_set`: set of grades (in [0, 1]) of the attributes.
- `concepts`: list of concepts (extent, intent).
- `implications`: extracted implications as an `ImplicationSet`.

Methods

Public methods:

- `FormalContext$new()`
- `FormalContext$is_empty()`
- `FormalContext$intent()`
- `FormalContext$extent()`
- `FormalContext$closure()`
- `FormalContext$obj_concept()`
- `FormalContext$att_concept()`
- `FormalContext$is_concept()`
- `FormalContext$is_closed()`
- `FormalContext$clarify()`
- `FormalContext$reduce()`
- `FormalContext$standardize()`
- `FormalContext$find_concepts()`
- `FormalContext$find_implications()`
- `FormalContext$to_transactions()`
- `FormalContext$save()`
- `FormalContext$load()`
- `FormalContext$dim()`
- `FormalContext$print()`
- `FormalContext$to_latex()`
- `FormalContext$plot()`
- `FormalContext$clone()`

Method `new()`: Creator for the Formal Context class

Usage:

```
FormalContext$new(I, remove_const = FALSE)
```

Arguments:

`I` (numeric matrix) The table of the formal context.

`remove_const` (logical) If `TRUE`, remove constant columns. The default is `FALSE`.

Details: Columns of `I` should be named, since they are the names of the attributes of the formal context.
If no `I` is used, the resulting `FormalContext` will be empty and not usable unless for loading a previously saved one.

Returns: An object of the `FormalContext` class.

Method `is_empty()`: Check if the `FormalContext` is empty

Usage:

```
FormalContext$is_empty()
```

Returns: `TRUE` if the `FormalContext` is empty, that is, has not been provided with a matrix, and `FALSE` otherwise.

Method `intent()`: Get the intent of a fuzzy set of objects

Usage:

```
FormalContext$intent(S)
```

Arguments:

`S` (`SparseSet`) The set of objects to compute the intent for.

Returns: A `SparseSet` with the intent.

Method `extent()`: Get the extent of a fuzzy set of attributes

Usage:

```
FormalContext$extent(S)
```

Arguments:

`S` (`SparseSet`) The set of attributes to compute the extent for.

Returns: A `SparseSet` with the intent.

Method `closure()`: Get the closure of a fuzzy set of attributes

Usage:

```
FormalContext$closure(S)
```

Arguments:

`S` (`SparseSet`) The set of attributes to compute the closure for.

Returns: A `SparseSet` with the closure.

Method `obj_concept()`: Object Concept

Usage:

```
FormalContext$obj_concept(object)
```

Arguments:

`object` (character) Name of the object to compute its associated concept

Returns: The object concept associated to the object given.

Method `att_concept()`**:** Attribute Concept

Usage:

```
FormalContext$att_concept(attribute)
```

Arguments:

`attribute` (character) Name of the attribute to compute its associated concept

Returns: The attribute concept associated to the attribute given.

Method `is_concept()`**:** Is a Concept?

Usage:

```
FormalContext$is_concept(C)
```

Arguments:

`C` A `SparseConcept` object

Returns: `TRUE` if `C` is a concept.

Method `is_closed()`**:** Testing closure of attribute sets

Usage:

```
FormalContext$is_closed(S)
```

Arguments:

`S` A `SparseSet` of attributes

Returns: `TRUE` if the set `S` is closed in this formal context.

Method `clarify()`**:** Clarify a formal context

Usage:

```
FormalContext$clarify(copy = FALSE)
```

Arguments:

`copy` (logical) If `TRUE`, a new `FormalContext` object is created with the clarified context, otherwise the current one is overwritten.

Returns: The clarified `FormalContext`.

Method `reduce()`**:** Reduce a formal context

Usage:

```
FormalContext$reduce(copy = FALSE)
```

Arguments:

`copy` (logical) If `TRUE`, a new `FormalContext` object is created with the clarified and reduced context, otherwise the current one is overwritten.

Returns: The clarified and reduced `FormalContext`.

Method `standardize()`**:** Build the Standard Context

Usage:

```
FormalContext$standardize()
```

Details: All concepts must be previously computed.

Returns: The standard context using the join- and meet- irreducible elements.

Method `find_concepts()`**:** Use Ganter Algorithm to compute concepts

Usage:

```
FormalContext$find_concepts(verbose = FALSE)
```

Arguments:

`verbose` (logical) TRUE will provide a verbose output.

Returns: A list with all the concepts in the formal context.

Method `find_implications()`**:** Use modified Ganter algorithm to compute both concepts and implications

Usage:

```
FormalContext$find_implications(save_concepts = TRUE, verbose = FALSE)
```

Arguments:

`save_concepts` (logical) `TRUE` will also compute and save the concept lattice. `FALSE` is usually faster, since it only computes implications.

`verbose` (logical) `TRUE` will provide a verbose output.

Returns: Nothing, just updates the internal fields `concepts` and `implications`.

Method `to_transactions()`**:** Convert the formal context to object of class `transactions` from the `arules` package

Usage:

```
FormalContext$to_transactions()
```

Returns: A `transactions` object.

Method `save()`**:** Save a `FormalContext` to RDS format

Usage:

```
FormalContext$save(filename = tempfile(fileext = ".rds"))
```

Arguments:

`filename` (character) Path of the RDS file where to store the `FormalContext`.

Returns: Invisibly the current `FormalContext`.

Method `load()`**:** Load a `FormalContext` from a RDS file

Usage:

```
FormalContext$load(filename)
```

Arguments:

`filename` (character) Path of the RDS file to load the `FormalContext` from.

Returns: The loaded `FormalContext`.

Method `dim()`**:** Dimensions of the formal context

Usage:

```
FormalContext$dim()
```

Returns: A vector with (number of objects, number of attributes).

Method `print()`**:** Prints the formal context

Usage:

```
FormalContext$print()
```

Returns: Prints information regarding the formal context.

Method `to_latex()`**:** Write the context in LaTeX format

Usage:

```
FormalContext$to_latex(
  label = "",
  caption = "",
  fraction = c("none", "frac", "dfrac", "sfrac")
)
```

Arguments:

`label` (character) The label for the table environment.

`caption` (character) The caption of the table.

`fraction` (character) If `none`, no fractions are produced. Otherwise, if it is `frac`, `dfrac` or `sfrac`, decimal numbers are represented as fractions with the corresponding LaTeX typesetting.

Returns: A table environment in LaTeX.

Method `plot()`**:** Plot the formal context table

Usage:

```
FormalContext$plot(to_latex = FALSE, ...)
```

Arguments:

`to_latex` (logical) If `TRUE`, export the plot as a `tikzpicture` environment that can be included in a `LaTeX` file.

`...` Other parameters to be passed to the `tikzDevice` that renders the lattice in `LaTeX`, or for the figure caption. See `Details`.

Details: Particular parameters that control the size of the `tikz` output are: `width`, `height` (both in inches), and `pointsize` (in points), that should be set to the font size used in the `documentclass` header in the `LaTeX` file where the code is to be inserted.
If a `caption` is provided, the whole `tikz` picture will be wrapped by a `figure` environment and the caption set.

Returns: If `to_latex` is `FALSE`, it returns nothing, just plots the graph of the formal context. Otherwise, this function returns the `LaTeX` code to reproduce the formal context plot.

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

Usage:

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

Arguments:

`deep` Whether to make a deep clone.

References

Guigues J, Duquenne V (1986). “Familles minimales d’implications informatives résultant d’un tableau de données binaires.” *Mathématiques et Sciences humaines*, *95*, 5-18.

Ganter B, Wille R (1999). *Formal concept analysis : mathematical foundations*. Springer. ISBN 3540627715.

Belohlavek R (2002). “Algorithms for fuzzy concept lattices.” In *Proc. Fourth Int. Conf. on Recent Advances in Soft Computing*. Nottingham, United Kingdom, 200-205.

Hahsler M, Grun B, Hornik K (2005). “arules - a computational environment for mining association rules and frequent item sets.” *J Stat Softw*, *14*, 1-25.

Examples

```
# Build and print the formal context
fc_planets <- FormalContext$new(planets)
print(fc_planets)

# Plot the formal context
fc_planets$plot()

# Define a set of attributes
S <- SparseSet$new(attributes = fc_planets$attributes)
S$assign(moon = 1, large = 1)

# Compute the closure of S
Sc <- fc_planets$closure(S)
# Is Sc a closed set?
fc_planets$is_closed(Sc)

# Clarify and reduce the formal context
fc2 <- fc_planets$reduce(TRUE)

# Find implications
fc_planets$find_implications()
```

`ImplicationSet` *R6 Class for Set of implications*

Description

This class implements the structure needed to store implications and the methods associated.

Methods

Public methods:

- `ImplicationSet$new()`
- `ImplicationSet$get_attributes()`

- ImplicationSet$[()
- ImplicationSet$to_arules()
- ImplicationSet$add()
- ImplicationSet$cardinality()
- ImplicationSet$is_empty()
- ImplicationSet$size()
- ImplicationSet$closure()
- ImplicationSet$recommend()
- ImplicationSet$apply_rules()
- ImplicationSet$to_basis()
- ImplicationSet$print()
- ImplicationSet$to_latex()
- ImplicationSet$get_LHS_matrix()
- ImplicationSet$get_RHS_matrix()
- ImplicationSet$filter()
- ImplicationSet$support()
- ImplicationSet$clone()

Method `new()`**:** Initialize with an optional name

Usage:

`ImplicationSet$new(...)`

Arguments:

`...` See Details.

Details: Creates and initialize a new `FormalContext` object. It can be done in two ways: `initialize(name,attributes,lhs,rhs)` or `initialize(rules)`
In the first way, the only mandatory argument is `attributes`, (character vector) which is a vector of names of the attributes on which we define the implications. Optional arguments are: `name` (character string), name of the implication set, `lhs` (a `dgCMatrix`), initial LHS of the implications stored and the analogous `rhs`.
The other way is used to initialize the `FormalContext` object from a `rules` object from package `arules`.

Returns: A new `ImplicationSet` object.

Method `get_attributes()`**:** Get the names of the attributes

Usage:

`ImplicationSet$get_attributes()`

Returns: A character vector with the names of the attributes used in the implications.

Method `[()`**:** Get a subset of the implication set

Usage:

`ImplicationSet$[(idx)`

Arguments:

`idx` (integer or logical vector) Indices of the implications to extract or remove. If logical vector, only `TRUE` elements are retained and the rest discarded.

Returns: A new `ImplicationSet` with only the rules given by the `idx` indices (if all `idx > 0` and all but `idx` if all `idx < 0`.

Method `to_arules()`: Convert to arules format

Usage:

```
ImplicationSet$to_arules(quality = TRUE)
```

Arguments:

`quality` (logical) Compute the interest measures for each rule?

Returns: A `rules` object as used by package `arules`.

Method `add()`: Add a precomputed implication set

Usage:

```
ImplicationSet$add(...)
```

Arguments:

`...` An `ImplicationSet` object, a `rules` object, or a pair `lhs`, `rhs` of `SparseSet` objects or `dgCMatrix`. The implications to add to this formal context.

Returns: Nothing, just updates the internal `implications` field.

Method `cardinality()`: Cardinality: Number of implications in the set

Usage:

```
ImplicationSet$cardinality()
```

Returns: The cardinality of the implication set.

Method `is_empty()`: Empty set

Usage:

```
ImplicationSet$is_empty()
```

Returns: `TRUE` if the set of implications is empty, `FALSE` otherwise.

Method `size()`: Size: number of attributes in each of LHS and RHS

Usage:

```
ImplicationSet$size()
```

Returns: A vector with two components: the number of attributes present in each of the LHS and RHS of each implication in the set.

Method `closure()`: Compute the semantic closure of a fuzzy set with respect to the implication set

Usage:

```
ImplicationSet$closure(S, reduce = FALSE, verbose = FALSE)
```

Arguments:

`S` (a `SparseSet` object) Fuzzy set to compute its closure. Use class `SparseSet` to build it.

`reduce` (logical) Reduce the implications using simplification logic?

`verbose` (logical) Show verbose output?

Returns: If `reduce == FALSE`, the output is a fuzzy set corresponding to the closure of `S`. If `reduce == TRUE`, a list with two components: `closure`, with the closure as above, and `implications`, the reduced set of implications.

Method `recommend()`**:** Generate a recommendation for a subset of the attributes

Usage:

```
ImplicationSet$recommend(S, attribute_filter)
```

Arguments:

`S` (a vector) Vector with the grades of each attribute (a fuzzy set).

`attribute_filter` (character vector) Names of the attributes to get recommendation for.

Returns: A fuzzy set describing the values of the attributes in `attribute_filter` within the closure of `S`.

Method `apply_rules()`**:** Apply rules to remove redundancies

Usage:

```
ImplicationSet$apply_rules(
  rules = c("composition", "generalization"),
  batch_size = 25000L,
  parallelize = FALSE,
  reorder = FALSE
)
```

Arguments:

`rules` (character vector) Names of the rules to use. See `details`.

`batch_size` (integer) If the number of rules is large, apply the rules by batches of this size.

`parallelize` (logical) If possible, should we parallelize the computation among different batches?

`reorder` (logical) Should the rules be randomly reordered previous to the computation?

Details: Currently, the implemented rules are `"generalization"`, `"simplification"`, `"reduction"` and `"composition"`.

Returns: Nothing, just updates the internal matrices for LHS and RHS.

Method `to_basis()`**:** Convert Implications to Canonical Basis

Usage:

```
ImplicationSet$to_basis()
```

Returns: The canonical basis of implications obtained from the current `ImplicationSet`

Method `print()`**:** Print all implications to text

Usage:

```
ImplicationSet$print()
```

Returns: A string with all the implications in the set.

Method `to_latex()`**:** Export to LaTeX

Usage:

```
ImplicationSet$to_latex(
  print = TRUE,
  ncols = 1,
  numbered = TRUE,
  numbers = seq(self$cardinality())
)
```

Arguments:

`print` (logical) Print to output?

`ncols` (integer) Number of columns for the output.

`numbered` (logical) If `TRUE` (default), implications will be numbered in the output.

`numbers` (vector) If `numbered`, use these elements to enumerate the implications. The default is to enumerate 1, 2, ..., but can be changed.

Returns: A string in LaTeX format that prints nicely all the implications.

Method `get_LHS_matrix()`**:** Get internal LHS matrix

Usage:

`ImplicationSet$get_LHS_matrix()`

Returns: A sparse matrix representing the LHS of the implications in the set.

Method `get_RHS_matrix()`**:** Get internal RHS matrix

Usage:

`ImplicationSet$get_RHS_matrix()`

Returns: A sparse matrix representing the RHS of the implications in the set.

Method `filter()`**:** Filter implications by attributes in LHS and RHS

Usage:

`ImplicationSet$filter(lhs = NULL, rhs = NULL, drop = FALSE)`

Arguments:

`lhs` (character vector) Names of the attributes to filter the LHS by. If `NULL`, no filtering is done on the LHS.

`rhs` (character vector) Names of the attributes to filter the RHS by. If `NULL`, no filtering is done on the RHS.

`drop` (logical) Remove the rest of attributes in RHS?

Returns: An `ImplicationSet` that is a subset of the current set, only with those rules which has the attributes in `lhs` and `rhs` in their LHS and RHS, respectively.

Method `support()`**:** Compute support of each implication

Usage:

`ImplicationSet$support()`

Returns: A vector with the support of each implication

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

Usage:

`ImplicationSet$clone(deep = FALSE)`

Arguments:

`deep` Whether to make a deep clone.

References

Hahsler M, Grun B, Hornik K (2005). "arules - a computational environment for mining association rules and frequent item sets." *J Stat Softw*, *14*, 1-25.

Belohlavek R, Cordero P, Enciso M, Mora Á, Vychodil V (2016). "Automated prover for attribute dependencies in data with grades." *International Journal of Approximate Reasoning*, *70*, 51-67.

Mora A, Cordero P, Enciso M, Fortes I, Aguilera G (2012). "Closure via functional dependence simplification." *International Journal of Computer Mathematics*, *89*(4), 510-526.

Examples

```
# Build a formal context
fc_planets <- FormalContext$new(planets)

# Find its implication basis
fc_planets$find_implications()

# Print implications
fc_planets$implications

# Cardinality and mean size in the ruleset
fc_planets$implications$cardinality()
sizes <- fc_planets$implications$size()
colMeans(sizes)

# Simplify the implication set
fc_planets$implications$apply_rules("simplification")
```

`planets` *Planets data*

Description

This dataset records some properties of the planets in our solar system.

Usage

```
planets
```

Format

A matrix with 9 rows (the planets) and 7 columns, representing additional features of the planets:

small 1 if the planet is small, 0 otherwise.

medium 1 if the planet is medium-sized, 0 otherwise.

large 1 if the planet is large, 0 otherwise.

near 1 if the planet belongs in the inner solar system, 0 otherwise.

far 1 if the planet belongs in the outer solar system, 0 otherwise.

moon 1 if the planet has a natural moon, 0 otherwise.

no_moon 1 if the planet has no moon, 0 otherwise.

Source

Wille R (1982). “Restructuring Lattice Theory: An Approach Based on Hierarchies of Concepts.” In Ordered Sets, pp. 445–470. Springer.

`print.conceptlist` *Print a list of concepts*

Description

Print a list of concepts

Usage

```
## S3 method for class 'conceptlist'
print(x, ...)
```

Arguments

`x`	A list of concepts as a result of subsetting a `ConceptLattice`
`...`	Another (unused) arguments.

Value

Nothing, just prints a list of concepts nicely.

Examples

```
# Build a formal context
fc_planets <- FormalContext$new(planets)

# Find its concepts
fc_planets$find_concepts()

# Print the first 3 concepts
fc_planets$concepts[1:3]
```

`SparseConcept` *R6 class for a fuzzy concept with sparse internal representation*

Description

This class implements the data structure and methods for fuzzy concepts.

Methods

Public methods:

- `SparseConcept$new()`
- `SparseConcept$get_extent()`
- `SparseConcept$get_intent()`
- `SparseConcept$print()`
- `SparseConcept$to_latex()`
- `SparseConcept$clone()`

Method `new()`**:** Creator for objects of class `SparseConcept`

Usage:

`SparseConcept$new(extent, intent)`

Arguments:

`extent` (`SparseSet`) The extent of the concept.

`intent` (`SparseSet`) The intent of the concept.

Returns: An object of class `SparseConcept`.

Method `get_extent()`**:** Internal `SparseSet` for the extent

Usage:

`SparseConcept$get_extent()`

Returns: The `SparseSet` representation of the extent.

Method `get_intent()`**:** Internal `SparseSet` for the intent

Usage:

`SparseConcept$get_intent()`

Returns: The `SparseSet` representation of the intent.

Method `print()`**:** Prints the concept to console

Usage:

`SparseConcept$print()`

Returns: A string with the elements of the set and their grades between brackets .

Method `to_latex()`**:** Write the concept in LaTeX format

Usage:

`SparseConcept$to_latex(print = TRUE)`

Arguments:

`print` (logical) Print to output?

Returns: The fuzzy concept in LaTeX.

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

Usage:

`SparseConcept$clone(deep = FALSE)`

Arguments:

`deep` Whether to make a deep clone.

Examples

```
# Build a formal context and find its concepts
fc_planets <- FormalContext$new(planets)
fc_planets$find_concepts()

# Print the first three concepts
fc_planets$concepts[1:3]

# Select the first concept:
C <- fc_planets$concepts[1][[1]]

# Get its extent and intent
C$get_extent()
C$get_intent()
```

`SparseSet` *R6 class for a fuzzy set with sparse internal representation*

Description

This class implements the data structure and methods for fuzzy sets.

Methods

Public methods:

- `SparseSet$new()`
- `SparseSet$assign()`
- `SparseSet$[()`
- `SparseSet$cardinal()`
- `SparseSet$get_vector()`
- `SparseSet$get_attributes()`
- `SparseSet$length()`

- SparseSet$print()
- SparseSet$to_latex()
- SparseSet$clone()

Method `new()`: Creator for objects of class `SparseSet`

Usage:

`SparseSet$new(attributes, M = NULL)`

Arguments:

`attributes` (character vector) Names of the attributes that will be available in the fuzzy set.

`M` (numeric vector or column `Matrix`) Values (grades) to be assigned to the attributes.

Details: If `M` is omitted, the fuzzy set is the empty set. Later, one can use the `assign` method to assign grades to any of its attributes.

Returns: An object of class `SparseSet`.

Method `assign()`: Assign grades to attributes in the set

Usage:

`SparseSet$assign(attributes = c(), values = c(), ...)`

Arguments:

`attributes` (character vector) Names of the attributes to assign a grade to.

`values` (numeric vector) Grades to be assigned to the previous `attributes`.

`...` `key` = `value` pairs, where the value `value` is assigned to the `key` attribute name.

Details: One can use both of: `S$assign(A = 1,B = 0.3)` `S$assign(attributes = c(A,B),values = c(1,0.3))`.

Method `[()`: Get elements by index

Usage:

`SparseSet$[(indices)`

Arguments:

`indices` (numeric, logical or character vector) The indices of the elements to return. It can be a vector of logicals where `TRUE` elements are to be retained.

Returns: A `SparseSet` but with only the required elements.

Method `cardinal()`: Cardinal of the SparseSet

Usage:

`SparseSet$cardinal()`

Returns: the cardinal of the `SparseSet`, counted as the sum of the degrees of each element.

Method `get_vector()`: Internal `Matrix`

Usage:

`SparseSet$get_vector()`

Returns: The internal sparse `Matrix` representation of the set.

Method `get_attributes()`: Attributes defined for the set

Usage:

`SparseSet$get_attributes()`

Returns: A character vector with the names of the attributes.

Method `length()`**:** Number of attributes

Usage:

`SparseSet$length()`

Returns: The number of attributes that are defined for this fuzzy set.

Method `print()`**:** Prints the set to console

Usage:

`SparseSet$print()`

Returns: A string with the elements of the set and their grades between brackets .

Method `to_latex()`**:** Write the set in LaTeX format

Usage:

`SparseSet$to_latex(print = TRUE)`

Arguments:

`print` (logical) Print to output?

Returns: The fuzzy set in LaTeX.

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

Usage:

`SparseSet$clone(deep = FALSE)`

Arguments:

`deep` Whether to make a deep clone.

Examples

```
S <- SparseSet$new(attributes = c("A", "B", "C"))
S$assign(A = 1)
print(S)
S$to_latex()
```

to_latex *Print a list of concepts to LaTeX*

Description

Print a list of concepts to LaTeX

Usage

```
to_latex(x)

## S3 method for class 'conceptlist'
to_latex(x)
```

Arguments

x	A `conceptlist` as result of subsetting a `ConceptLattice`

Value

Nothing, just prints a list of concepts in LaTeX nicely.

Examples

```
# Build a formal context
fc_planets <- FormalContext$new(planets)

# Find its concepts
fc_planets$find_concepts()

# Print the first 3 concepts to latex
to_latex(fc_planets$concepts[1:3])
```

vegas *Data for Tourist Destination in Las Vegas*

Description

The dataset `vegas` is the binary translation of the Las Vegas Strip dataset (@moro2017stripping), which records more than 500 TripAdvisor reviews of hotels in Las Vegas Strip. The uninformative attributes (such as the user continent or the weekday of the review) are removed.

Usage

```
vegas
```

Format

A matrix with 504 rows and 25 binary columns. Column names are related to different features of the hotels:

Period of Stay 4 categories are present in the original data, which produces as many binary variables: `Period of stay=Dec-Feb`, `Period of stay=Mar-May`, `Period of stay=Jun-Aug` and `Period of stay=Sep-Nov`.

Traveler type Five binary categories are created from the original data: `Traveler type=Business`, `Traveler type=Couples`, `Traveler type=Families`, `Traveler type=Friends` and `Traveler type=Solo`.

Pool, Gym, Tennis court, Spa, Casino, Free internet Binary variables for the services offered by each destination hotel

Stars Five binary variables are created, according to the number of stars of the hotel, `Stars=3`, `Stars=3.5`, `Stars=4`, `Stars=4.5` and `Stars=5`.

Score The score assigned in the review, from `Score=1` to `Score=5`.

Source

Moro, S., Rita, P., & Coelho, J. (2017). Stripping customers' feedback on hotels through data mining: The case of Las Vegas Strip. Tourism Management Perspectives, 23, 41-52.

`%==%` *Equality in Sets and Concepts*

Description

Equality in Sets and Concepts

Usage

```
C1 %==% C2
```

Arguments

`C1`	A `SparseSet` or `SparseConcept`
`C2`	A `SparseSet` or `SparseConcept`

Details

Both `C1` and `C2` must be of the same class.

Value

Returns `TRUE` if `C1` is equal to `C2`.

Examples

```
# Build two sparse sets
S <- SparseSet$new(attributes = c("A", "B", "C"))
S$assign(A = 1)
T <- SparseSet$new(attributes = c("A", "B", "C"))
T$assign(A = 1)

# Test whether S and T are equal
S %==% T
```

`%<=%` *Partial Order in Sets and Concepts*

Description

Partial Order in Sets and Concepts

Usage

```
C1 %<=% C2
```

Arguments

C1	A `SparseSet` or `SparseConcept`
C2	A `SparseSet` or `SparseConcept`

Details

Both `C1` and `C2` must be of the same class.

Value

Returns `TRUE` if concept `C1` is subconcept of `C2` or if set `C1` is subset of `C2`.

Examples

```
# Build two sparse sets
S <- SparseSet$new(attributes = c("A", "B", "C"))
S$assign(A = 1)
T <- SparseSet$new(attributes = c("A", "B", "C"))
T$assign(A = 1, B = 1)

# Test whether S is subset of T
S %<=% T
```

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