vivid Documentation

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Contents: This module provides the rules of diagrammatic inference.

`inference_rules.`**`diagram_reiteration`**(*context*)

Perform Diagram Reiteration to retrieve the current diagram, i.e., from lemma 19: $(\beta; (\sigma; \rho)) \models (\sigma; \rho)$.

Parameters **`context`** (`Context`) – The Context object $(\beta; (\sigma; \rho))$ from which to retrieve the current NamedState object $(\sigma; \rho)$.

Returns The NamedState object $(\sigma; \rho)$ of the Context object $(\beta; (\sigma; \rho))$ in `context` parameter.

Return type *NamedState*

`inference_rules.`**`diagrammatic_absurdity`**(*context*, *named_state*, *attribute_interpretation*)

Verify that the NamedState object in the `named_state` parameter can be obtained from the Context object in the `context` parameter by absurdity, using the AttributeInterpretation object provided in the `attribute_interpretation` parameter to interpet truth values.

To show $(\sigma'; \rho')$ **by absurdity**, we must show $(\beta \cup \{\textbf{false}\}; (\sigma; \rho)) \models (\sigma'; \rho')$.

By lemma 20, $(\beta \cup \{\textbf{false}\}; (\sigma; \rho)) \models (\sigma'; \rho')$, thus it suffices to show that a call to `entails_named_state` with context $(\beta; (\sigma; \rho))$ and named state $(\sigma'; \rho')$, that is, $(\beta; (\sigma; \rho)) \models (\sigma'; \rho')$ holds, implicitly assuming that some $F \in \beta$ evaulates to **false** (as then no world can satisify the context, i.e., for any world $(w; \widehat{\rho})$ derivable from the context $(\beta; (\sigma; \rho))$, $(w; \widehat{\rho}) \not\models_{\chi} (\beta; (\sigma; \rho))$ and thus `entails_named_state` will always hold yielding $(\sigma'; \rho')$ **by absurdity** regardless of the NamedState object $(\sigma'; \rho')$ provided in the `named_state` parameter)

Parameters

- **`context`** (`Context`) – The Context object $(\beta; (\sigma; \rho))$.
- **`named_state`** (`NamedState`) – The NamedState object $(\sigma'; \rho')$.
- **`attribute_interpretation`** (`AttributeInterpretation`) –

Returns Whether or not $(\sigma'; \rho')$ **by absurdity**, that is, whether or not $(\beta; (\sigma; \rho)) \models (\sigma'; \rho')$ holds.

Return type `bool`

Raises **`TypeError`** – `context` parameter must be a Context object, `named_state` parameter must be a NamedState object and `attribute_interpretation` parameter must be an AttributeInterpretation object.

`inference_rules.`**`diagrammatic_to_diagrammatic`**(*context*, *inferred_named_state*, *named_states*, *attribute_interpretation*, *variable_assignment*, **formulae*)

Verify that on the basis of the present diagram $(\sigma; \rho)$ of the Context object $(\beta; (\sigma; \rho))$ in the `context` parameter and some set of Formula objects $F_1, \dots, F_k, k \geq 0$ provided as optional positional arguments in the `formulae` parameter, that for each NamedState object $(\sigma_1; \rho_1), \dots, (\sigma_n; \rho_n), n > 0$, contained in the `named_states` parameter, a NamedState object $(\sigma'; \rho')$ provided in the `inferred_named_state` parameter can be derived in every one of these n cases.

This is rule [C1].

This function works as follows:

1. If $k > 0$, compute the basis $\mathcal{B}(F_1, \rho, \chi) \cup \cdots \cup \mathcal{B}(F_k, \rho, \chi)$ of $F_1, \dots, F_k$ and determine if the NamedState objects $(\sigma_1; \rho_1), \dots, (\sigma_n; \rho_n)$ provided in the `named_states` parameter form an exhuastive set of possibilities on this basis.

2. Determine if the proviso $(\sigma; \rho) \Vdash_{\{F_1, \dots, F_k\}} \{(\sigma_1; \rho_1), \dots, (\sigma_n; \rho_n)\}$ (where $k \geq 0$) holds.

3. Return the evaluation of $(\beta \cup \{F_1, \dots, F_k\}; (\sigma; \rho)) \models (\sigma'; \rho')$.

Parameters

- **context** (`Context`) – The Context object $(\beta; (\sigma; \rho))$ from which the present diagram $(\sigma; \rho)$ comes from.
- **inferred_named_state** (`NamedState`) – The NamedState object $(\sigma'; \rho')$ derivable in the $n > 0$ cases provided by the NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)$ in the `named_state` parameter.
- **named_states** (`list`) – The NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n), n > 0$ functioning as the set of n exhaustive cases from which F can be derived.
- **attribute_interpretation** (`AttributeInterpretation`) – The AttributeInterpretation object to use for the interpretation of truth values and the computation of the basis of $F_1, \ldots, F_k$.
- **variable_assignment** (VariableAssignment | `None`) – The VariableAssignment object χ to consider when computing the basis $\mathcal{B}(F_1, \rho, \chi) \cup \cdots \cup \mathcal{B}(F_k, \rho, \chi)$ of $F_1, \ldots, F_k$ or `None` if all terms of the $F_1, \ldots, F_k$ are in ρ.
- **formulae** (`Formula`) – The $k \geq 0$ Formula objects $F_1, \ldots, F_k$ to use in the computation of the basis, computation of the proviso and the evaluation of $(\beta \cup \{F_1, \ldots, F_k\}; (\sigma; \rho)) \models (\sigma'; \rho')$.

Returns The result of the evaluation of $(\beta \cup \{F_1, \ldots, F_k\}; (\sigma; \rho)) \models (\sigma'; \rho')$.

Return type `bool`

Raises **ValueError** – If $k > 0$, the NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n), n > 0$ are not exhaustive on the basis of the Formula objects $F_1, \ldots, F_k$ or the proviso $(\sigma; \rho) \Vdash_{\{F_1,\ldots,F_k\}} \{(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)\}$ (where $k \geq 0$) does not hold.

`inference_rules.`**`diagrammatic_to_sentential`**(*context, F, named_states, attribute_interpretation, variable_assignment, *formulae*)

Verify that on the basis of the present diagram $(\sigma; \rho)$ of the Context object $(\beta; (\sigma; \rho))$ in the `context` parameter and some set of Formula objects $F_1, \ldots, F_k, k \geq 0$ provided as optional positional arguments in the `formulae` parameter, that for each NamedState object $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n), n > 0$, contained in the `named_states` parameter, a Formula object F provided in the `F` parameter can be derived in every one of these n cases.

This is rule [C3].

This function works as follows:

1. If $k > 0$, compute the basis $\mathcal{B}(F_1, \rho, \chi) \cup \cdots \cup \mathcal{B}(F_k, \rho, \chi)$ of $F_1, \ldots, F_k$ and determine if the NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)$ provided in the `named_states` parameter form an exhuastive set of possibilities on this basis.

2. Determine if the proviso $(\sigma; \rho) \Vdash_{\{F_1,\ldots,F_k\}} \{(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)\}$ (where $k \geq 0$) holds.

3. Return the evaluation of $(\beta \cup \{F_1, \ldots, F_k\}; (\sigma; \rho)) \models F$.

Parameters

- **context** (`Context`) – The Context object $(\beta; (\sigma; \rho))$ from which the present diagram $(\sigma; \rho)$ comes from.
- **F** (`Formula`) – The Formula object F derivable in the $n > 0$ cases provided by the NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)$ in the `named_state` parameter.
- **named_states** (`list`) – The NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n), n > 0$ functioning as the set of n exhaustive cases from which F can be derived.

- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation object to use for the interpretation of truth values and the computation of the basis of $F_1, \ldots, F_k$.
- **`variable_assignment`** (VariableAssignment | `None`) – The VariableAssignment object χ to consider when computing the basis $\mathcal{B}(F_1, \rho, \chi) \cup \cdots \cup \mathcal{B}(F_k, \rho, \chi)$ of $F_1, \ldots, F_k$ or `None` if all terms of the $F_1, \ldots, F_k$ are in ρ.
- **`formulae`** (`Formula`) – The $k \geq 0$ Formula objects $F_1, \ldots, F_k$ to use in the computation of the basis, computation of the proviso and the evaluation of $(\beta \cup \{F_1, \ldots, F_k\}; (\sigma; \rho)) \models F$.

Returns The result of the evaluation of $(\beta \cup \{F_1, \ldots, F_k\}; (\sigma; \rho)) \models F$.

Return type `bool`

Raises `ValueError` – If $k > 0$, the NamedState objects $(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n), n > 0$ are not exhaustive on the basis of the Formula objects $F_1, \ldots, F_k$ or the proviso $(\sigma; \rho) \Vdash_{\{F_1, \ldots, F_k\}} \{(\sigma_1; \rho_1), \ldots, (\sigma_n; \rho_n)\}$ (where $k \geq 0$) does not hold.

`inference_rules.`**`observe`**(*context*, *formula*, *attribute_interpretation*)

Determine if a Formula object F given by `formula` parameter can be observed in a Context object $(\beta; (\sigma; \rho))$ given by `context` parameter, using the AttributeInterpretation object in the `attribute_interpretation` parameter to interpret truth values, i.e., determine if **observe** F holds in $(\beta; (\sigma; \rho))$.

Parameters

- **`context`** (`Context`) – The Context object in which the Formula object can potentially be observed.
- **`formula`** (`Formula`) – The (potentially) observable Formula object.
- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation object to use to interpet truth values in the `context` and `formula` parameters.

Returns Whether or not **observe** F holds in $(\beta; (\sigma; \rho))$, that is, whether or not $(\beta; (\sigma; \rho)) \models F$.

Return type `bool`

`inference_rules.`**`sentential_to_diagrammatic`**(*context*, *F1*, *F2*, *named_state*, *attribute_interpretation*, *variable_assignment=None*)

Verify that in the case of a disjunction $F_1 \vee F_2$ holding, a NamedState object in the `named_state` parameter follows either way, using the AttributeInterpretation object in the `attribute_interpretation` parameter to interpet truth values.

This is rule [C2].

This function works as follows:

1. Verify the disjunction $F_1 \cup F_2$ given by `F1` and `F2` parameters holds in the Context object $(\beta; (\sigma; \rho))$ given by `context` parameter.

2. Generate two new Context objects $\gamma_1 = (\beta_1; (\sigma; \rho))$ where $\beta_1 = \beta \cup F_1$ and $\gamma_2 = (\beta_2; (\sigma; \rho))$ where $\beta_2 = \beta \cup F_2$.

3. For all possible worlds $\left(w'; \widehat{\rho'}\right)$ and variable assignments χ of the NamedState object $(\sigma'; \rho')$, determine if the world $\left(w'; \widehat{\rho'}\right)$ satisfies both Context objects γ_1 and γ_2, that is $\left(w'; \widehat{\rho'}\right) \models \gamma_1 \bigwedge \left(w'; \widehat{\rho'}\right) \models \gamma_2$.

4. If any world $\left(w'; \widehat{\rho'}\right)$ and variable assignments χ of the NamedState object $(\sigma'; \rho')$ does not satisify both γ_1 and γ_2, then **sentential-to-diagrammatic** does not hold, otherwise, **sentential-to-diagrammatic** holds.

In this way, we capture the idea that any world $\left(w'; \widehat{\rho'}\right)$ and variable assignments χ of the NamedState object $(\sigma'; \rho')$ (and thus the NamedState object $(\sigma'; \rho')$ itself) follows from the context $(\beta \cup \{F_1 \vee F_2\}; (\sigma; \rho))$ in either case of the disjunction $F_1 \vee F_2$.

Parameters

- **`context`** (`Context`) – The Context object $(\beta; (\sigma; \rho))$ in which the Formula objects in the parameters `F1` and `F2` apply and in which the NamedState object $(\sigma'; \rho')$ in `named_state` parameter would follow.
- **`F1`** (`Formula`) – The left operand of the disjunction F_1.
- **`F2`** (`Formula`) – The right operand of the disjunction F_2.
- **`named_state`** (`NamedState`) – The NamedState object $(\sigma'; \rho')$ that potentially follows in either case of the disjunction.
- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation object to use for the interpretation of truth values.
- **`variable_assignment`** (VariableAssignment | `None`) – The optional VariableAssignment object χ to consider in the interpretation of truth values.

Returns Whether or not **sentential-to-diagrammatic** holds.

Return type `bool`

Raises **`ValueError`** – The disjunction $F_1 \vee F_2$ does not hold.

`inference_rules.`**`sentential_to_sentential`**(*context*, *F1*, *F2*, *G*, *attribute_interpretation*, *variable_assignment=None*)

Verify that a disjunction $F_1 \vee F_2$ holds in the Context object in the `context` parameter and that a formula *G* follows in either case, using the AttributeInterpretation object in the `attribute_interpretation` parameter to interpret truth values.

To perform the **sentential-to-sentential** inference, first the disjunction $F_1 \vee F_2$ is verified. Then the truth values of $F_1 \Rightarrow G$ and $F_1 \Rightarrow G$ are determined. If either $F_1 \Rightarrow G$ or $F_1 \Rightarrow G$ do not hold, then **sentential-to-sentential** does not hold, otherwise, **sentential-to-sentential** holds.

Parameters

- **`context`** (`Context`) – The Context in which the the Formula objects in the parameters `F1`, `F2` apply and in which the Formula object `G` would follow.
- **`F1`** (`Formula`) – The left operand of the disjunction F_1.
- **`F2`** (`Formula`) – The right operand of the disjunction F_2.
- **`G`** (`Formula`) – The Formula object potentially following the disjunction in either case.
- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation object to use for interpeting truth values.
- **`variable_assignment`** (VariableAssignment | `None`) – The optional VariableAssignment object χ to consider in the interpretation of truth values.

Returns Whether or not **sentential-to-sentential** holds.

Return type `bool`

Raises **`ValueError`** – The disjunction $F_1 \vee F_2$ does not hold.

`inference_rules.`**`thinning`**(*context*, *named_state*, *assumption_base=None*, *attribute_interpretation=None*)

Verify that NamedState object in `named_state` parameter can be obtained by thinning from the

NamedState object contained in Context object in `context` parameter w.r.t. the AssumptionBase object given by the `assumption_base` parameter, using the AttributeInterpretation object in the `attribute_interpretation` parameter to interpret truth values.

By Corollary 26, if $(\sigma;\rho) \Vdash_{\{F_1,\ldots,F_n\}} (\sigma';\rho')$ then $(\{F_1,\ldots,F_n\};(\sigma;\rho)) \models (\sigma';\rho')$.

Then, by weakening, $(\beta \cup \{F_1,\ldots,F_n\};(\sigma;\rho)) \models (\sigma';\rho')$ and thinning holds, thus it suffices to show that a call to `entails_named_state` with context $(\{F_1,\ldots,F_n\};(\sigma;\rho))$ and named state $(\sigma';\rho')$, that is $(\sigma;\rho) \Vdash_{\{F_1,\ldots,F_n\}} (\sigma';\rho')$, holds to show that thinning holds.

Parameters

- **`context`** (`Context`) – The Context object $(\beta;(\sigma;\rho))$.
- **`named_state`** (`NamedState`) – The NamedState object $(\sigma';\rho')$
- **`assumption_base`** (AssumptionBase | `None`) – The set of Formula objects to thin with $\{F_1,\ldots,F_n\}$ if thinning is to be done with any Formula (i.e., $n > 0$), otherwise `None`.
- **`attribute_interpretation`** (AttributeInterpretation | `None`) – The AttributeInterpretation object to use to interpret truth values if $n > 0$, otherwise `None`.

Returns Whether or not thinning holds, i.e., the result of $(\sigma;\rho) \Vdash_{\{F_1,\ldots,F_n\}} (\sigma';\rho')$

Return type `bool`

Raises **`TypeError`** – `context` parameter must be a Context object and `named_state` parameter must be a NamedState object.

`inference_rules.`**`widening`**(*context*, *named_state*, *attribute_interpretation=None*)

Verify that NamedState object in `named_state` parameter can be obtained from Context object in `context` parameter by widening, using the AttributeInterpretation object in the `attribute_interpretation` parameter to interpret truth values.

Parameters

- **`context`** (`Context`) – The Context object $(\beta;(\sigma;\rho))$.
- **`named_state`** (`NamedState`) – The NamedState object $(\sigma';\rho')$
- **`attribute_interpretation`** (AttributeInterpretation | `None`) – The AttributeInterpretation object to use to interpret truth values if widening should consider the AssumptionBase object of the `context` parameter, otherwise `None`.

Returns Whether or not NamedState object $(\sigma';\rho')$ in `named_state` parameter can be obtained from Context object $(\beta;(\sigma;\rho))$ in `context` parameter can be obtained by widening, i.e., whether or not $(\beta;(\sigma;\rho)) \models (\sigma';\rho')$

Return type `bool`

Raises **`TypeError`** – `context` parameter must be a Context object and `named_state` parameter must be a NamedState object.

assignment module.

class `assignment.`**`Assignment`**(*vocabulary*, *attribute_system*)

Assignment superclass for constant/variable assignments.

Variables

- ***`vocabulary`*** – a reference to the Vocabulary object the Assignment is defined over.
- ***`attribute_system`*** – a copy of the AttributeSystem the Assignment originates from.
- **`_is_Assignment`** – An identifier to use in place of type or isinstance.

`__eq__`(*other*)
Determine if two Assignment objects are equal via the == operator.

`__init__`(*vocabulary*, *attribute_system*)
Construct a base Assignment.

Parameters

- **`vocabulary`** (`Vocabulary`) – The Vocabulary the Assignment is defined over.
- **`attribute_system`** (`AttributeSystem`) – The AttributeSystem from which the objects in the Assignment come from.

Raises `TypeError` – `vocabulary` parameter must be a Vocabulary object and `attribute_system` parameter must be an AttributeSystem object.

`__ne__`(*other*)
Determine if two Assignment objects are not equal via the != operator.

assumption_base module.

class `assumption_base.`**`AssumptionBase`**(**formulae*)
AssumptionBase class.

This class functions as a container for a finite set of Formulae over a single Vocabulary, i.e., β.

Variables

- **`formulae`** – The set of Formula objects contained in the AssumptionBase object.
- ***`vocabulary`*** – The underlying Vocabulary object the AssumptionBase is defined over.
- **`_is_AssumptionBase`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)
Add all Formula objects in another AssumptionBase or a single Formula object to an AssumptionBase object via the + operator.

Raises

- **`TypeError`** – Only Formula or AssumptionBase objects can be added to an AssumptionBase object.
- **`ValueError`** – Cannot add objects with different underlying Vocabulary objects and duplicate Formula objects are not permitted.

`__contains__`(*item*)
Overloaded `in` operator for AssumptionBase. Determine if a formula is contained in this AssumptionBase object.

Parameters `key` (Formula | `str`) – The Formula object or name of Formula object to test for membership in this AssumptionBase.

`__deepcopy__`(*memo*)
Deepcopy an AssumptionBase object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

`__eq__`(*other*)
Determine if two AssumptionBase objects are equal via the == operator.

`__getitem__`(*key*)
Retrive the Formula correspond to key given by `key` parameter via indexing (e.g. `AssumptionBase[key]`).

Parameters **key** (`int` | `str` | Formula) – The key to use for indexing a Formula in the AssumptionBase.

Raises

- **`IndexError`** – `int` key is out of range.
- **`KeyError`** – `key` parameter does not correspond to any Formula object in the AssumptionBase.
- **`TypeError`** – `key` parameter must be an `int`, `str`, or Formula object.

`__iadd__`(*other*)
Add all Formula objects in another AssumptionBase or a single Formula object to this AssumptionBase object via the + operator.

Raises

- **`TypeError`** – Only Formula or AssumptionBase objects can be added to an AssumptionBase object.
- **`ValueError`** – Cannot add objects with different underlying Vocabulary objects and duplicate Formula objects are not permitted.

`__init__`(**formulae*)
Construct an AssumptionBase object.

Parameters **formulae** (*`Formula|Vocabulary`*) – Any amount of Formula objects or a single Vocabulary object if AssumptionBase no Formula objects are provided.

Raises

- **`TypeError`** – All optional positional arguments provided must be Formula objects or only a single Vocabulary object may be provided.
- **`ValueError`** – All Formula objects provided as optional positional arguments must share the same Vocabulary.

`__iter__`()
Provides an iterator for AssumptionBase (e.g. "`for formula in AssumptionBase:`").

`__len__`()
Determine the length of an AssumptionBase object via the `len` built-in function e.g.(`len(AssumptionBase)`).

`__ne__`(*other*)
Determine if two AssumptionBase objects are not equal via the != operator.

`__repr__`()
Return a string representation of the AssumptionBase object.

`__str__`()
Return a readable string representation of the AssumptionBase object.

attribute module.

class `attribute.`**`Attribute`**(*label*, *value_set*)
Attribute Class, i.e., a finite set A with an associated label l.

Variables

- **`label`** – the associated label l of the Attribute A.
- **`value_set`** – the set of values that the attribute can take on (e.g {small,large}).
- **`_is_Attribute`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)
Combine an Attribute object with another Attribute object, a Relation object, an AttributeStructure object or an AttributeSystem object via the + operator.

Parameters **`other`** (`Attribute|Relation|AttributeStructure|AttributeSystem`) – The object to combine with the Attribute. If an Attribute, Relation, or AttributeStructure object is provided, an AttributeStructure object is returned; if an AttributeSystem object is provided, an AttributeSystem is returned.

Raises **`TypeError`** – other parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.

`__deepcopy__`(*memo*)
Deepcopy an Attribute object via the `copy.deepcopy` method.

`__eq__`(*other*)
Determine if two Attribute objects are equal via the == operator.

`__hash__`()
Hash implementation for set functionality of Attribute objects.

`__init__`(*label*, *value_set*)
Construct an Attribute object.

Parameters

- **`label`** (`str`) – The label *l* to associate with the Attribute object.
- **`value_set`** (`list|ValueSet`) – The set of values the Attribute can take on.

Raises **`TypeError`** – `label` parameter must be a string and `value_set` parameter must be either a ValueSet object or a list.

`__ne__`(*other*)
Determine if two Attribute objects are not equal via the != operator.

`__repr__`()
Return a string representation of the Attribute object with the following form: "*label:* {v_1, . . . ,v_n}."

`__str__`()
Return a readable string representation of the Attribute object with the following form: "*label:* {v_1, . . . ,v_n}."

`_key`()
Private key function for hashing.

Returns 2-tuple consisting of (label, valueset)

Return type `tuple`

attribute_interpretation module.

class `attribute_interpretation.`**`AttributeInterpretation`**(*vocabulary*, *attribute_structure*, *mapping*, *profiles*)
AttributeInterpretation class. Build an interpretation table; that is, a mapping I that assigns, to each relation symbol $R \in$ R of arity *n*:

1. a relation $R^I \in \mathcal{R}$ of some arity *m*, called the **realization** of *R*:

$$R^I \subset A_{i_1} \times \cdots \times A_{i_m}$$

(where we might have $m \neq n$); and

2. a list of *m* pairs

$$[(l_{i_1}; j_1) \cdots (l_{i_m}; j_m)]$$

called the **profile** of *R* and denoted by $Prof(R)$, with $1 \leq j_x \leq n$ for $x = 1, \ldots, m$

Variables

- ***vocabulary*** – The Vocabulary object of the interpretation.
- ***attribute_structure*** – The AttributeStructure object the interpretation is into.
- **mapping** – The mapping R $\rightarrow \mathcal{R}$.
- **profiles** – A list of profiles $[(l_{i_1}; j_1) \cdots (l_{i_m}; j_m)]$; one for each realization.
- **table** – The interpretation table of the attribute interpretation.
- **relation_symbols** – A copy of the RelationSymbol objects from the Vocabulary (for convenient access).
- **is_AttributeInterpretation** – An identifier to use in place of type or isinstance.

__deepcopy__(*memo*)
Deepcopy an AttributeInterpretation object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

__eq__(*other*)
Determine if two AttributeInterpretation objects are equal via the == operator.

__init__(*vocabulary*, *attribute_structure*, *mapping*, *profiles*)
Construct an AttributeInterpretation object.

Parameters

- **vocabulary** (`Vocabulary`) – The Vocabulary object to define the AttributeInterpretation over.
- **attribute_structure** (`AttributeStructure`) – The AttributeStructure object for which to define the AttributeInterpretation into.
- **mapping** (`dict`) – The mapping from the RelationSymbol objects of the Vocabulary object in the `vocabulary` parameter to the Relation objects of the AttributeStructure object in the `attribute_structure` parameter; the keys being RelationSymbol objects and values being `int`s corresponding to the subscripts of the AttributeStructure Relation objects.
- **profiles** (`list`) – A list of realizations corresponding to the mapping wherein each element is a list where the first element is the RelationSymbol and the following elements are 2-tuples $(l_{i_k}; j_k)$.

Raises

- **TypeError** – `vocabulary` parameter must be a Vocabulary object, `attribute_structure` parameter must be an AttributeStructure object, `mapping` parameter myst be a `dict` and `profile` parameter must be a `list`.
- **ValueError** – All keys in `mapping` parameter must be RelationSymbol objects and all values must be unique `int`s, duplicate profiles are not permitted (determined by repeated RelationSymbol objects), the set of RelationSymbol's provided in `mapping` parameter and the set of RelationSymbol's in `vocabulary` parameter and the set of RelationSymbol's provided in `profile` parameter must all be equal, all subscripts provided in `mapping` parameter keys must be valid subscripts of Relation objects in `attribute_structure` parameter, all l_{i_k} in $(l_{i_k}; j_k)$ 2-tuples provided in each realization of `profile` parameter must be a label of some Attribute object in `attribute_structure` parameter, and all j_k in $(l_{i_k}; j_k)$ 2-tuples provided in each

realization of `profile` parameter must be between 1 and the arity of the RelationSymbol object of the realization.

`__iter__`()
Provide an iterator for AttributeInterpretation objects interpretation table.

`__ne__`(*other*)
Determine if two AttributeInterpretation objects are not equal via the != operator.

`__repr__`()
Return a string representation of the AttributeInterpretation object.

`__str__`()
Return a readable string representation of the AttributeInterpretation object.

attribute_structure module.

class `attribute_structure.`**`AttributeStructure`**(**args*)
AttributeStructure class composed of Attribute and Relation objects, i.e.,

$$\mathcal{A} = (\{A_1, \ldots, A_\mathrm{k}\}; \mathcal{R})$$

The AttributeStructure class uses the `total_ordering` decorator so strict subsets, supersets and strict supersets are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- **`attributes`** – list of Attribute objects (i.e., $\{A_1, \ldots, A_\mathrm{k}\}$); always maintained as a list.
- **`relations`** – dictionary of relations (i.e., $\mathcal{R}$).
- **`_is_AttributeStructure`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)
Add an Attribute, Relation, or AttributeStructure object via the + operator.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure|AttributeSystem`*) – The object to combine with the AttributeStructure. If an Attribute, Relation, or AttributeStructure object is provided, an AttributeStructure object is returned; if an AttributeSystem object is provided, an AttributeSystem is returned.

Raises

- **`TypeError`** – `other` parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **`ValueError`** – Duplicate Attribute labels not permitted, duplicate subscripts are not permitted and every Relation's $D(R)$ must be a subset of Attribute labels in the AttributeStructure.

`__contains__`(*key*)
Determine if Attribute, Relation, Attribute corresponding to label in `key` or Relation corresponding to subscript in `key` is contained by AttributeStructure via `in` operator.

Parameters **`key`** (*`Attribute|Relation|str|int`*) – The key to use when checking for membership.

Raises **`TypeError`** – `key` must be an Attribute object, Relation object, `str`, or `int`.

`__deepcopy__`(*memo*)
Deepcopy an AttributeStructure object via the `copy.deepcopy` method.

`__eq__`(*other*)
Determine if two AttributeStructure objects are equal via the == operator.

`__getitem__`(*key*)
Retrieve a reference to the Attribute or Relation in the AttributeStructure via the key provided.

Parameters **`key`** (*`Attribute|Relation|str|int`*) – The Attribute, Relation, label, or subscript to use when attempting to find the cooresponding Attribute or Relation.

Raises

- **`KeyError`** – Attribute or Relation provided in `key` not found in AttributeStructure or no Relation with subscript provided in `key` found in AttributeStructure.
- **`TypeError`** – `key` is not an Attribute, Relation, `int`, or `str`.
- **`ValueError`** – no Attribute has label provided in `key` or no Relation has subscript provided in `key`.

`__iadd__`(*other*)
Add an Attribute, Relation, or AttributeStructure object via the += operator.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure|AttributeSystem`*) – The object to combine with the AttributeStructure. If an Attribute, Relation, or AttributeStructure object is provided, an AttributeStructure object is returned; if an AttributeSystem object is provided, an AttributeSystem is returned.

Raises

- **`TypeError`** – other parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **`ValueError`** – Duplicate Attribute labels not permitted, duplicate subscripts are not permitted and every Relation's $D(R)$ must be a subset of Attribute labels in the AttributeStructure.

`__init__`(**args*)
Construct an AttributeStructure object.

Parameters **`args`** (*`Attribute|Relation`*) – Attribute or Relation objects.

Raises

- **`TypeError`** – all optional positional arguments must be Attribute or Relation objects.
- **`ValueError`** – Duplicate Attribute labels are not permitted, Duplicate Relation subscripts are not permitted, and each Relation's $D(R)$ must be a subset of the cartesian product of some combination of the labels of the Attributes provided.

`__isub__`(*other*)
Remove Attribute's or Relation's via -= operator. If an AttributeStructure is provided, all Attributes and Relations within that AttributeStructure will be removed.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure`*) – The Attribute, Relation, or AttributeStructure to remove.

Raises

- **`KeyError`** – Invalid Relation provided.
- **`TypeError`** – Only Attribute, Relation, or AttributeStructure objects can be removed.
- **`ValueError`** – Invalid Attribute provided if `other` is Attribute, Relation or Attribute not contained in this AttributeStructure if `other` is AttributeStructure or some Relation's $D(R)$ is invalid after Attribute removal.

`__le__`(*other*)
Overloaded <= operator. Determine if this AttributeStructure is a subset of other.

`__ne__`(*other*)
Determine if two AttributeStructure objects are not equal via the $!=$ operator.

`__repr__`()
Return a string representation of the AttributeStructure object.

`__str__`()
Return a readable string representation of the AttributeStructure object.

`__sub__`(*other*)
Remove Attribute's or Relation's via $-$ operator. If an AttributeStructure is provided, all Attributes and Relations within that AttributeStructure will be removed.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure`*) – The Attribute, Relation, or AttributeStructure to remove.

Raises

- **`KeyError`** – Invalid Relation provided.
- **`TypeError`** – Only Attribute, Relation, or AttributeStructure objects can be removed.
- **`ValueError`** – Invalid Attribute provided if `other` is Attribute, Relation or Attribute not contained in this AttributeStructure if `other` is AttributeStructure or some Relation's $D(R)$ is invalid after Attribute removal.

`get_cardinality`()
Return cardinality of this AttributeStructure.

Returns The cardinality of the AttributeStructure, i.e., the amount of Attribute objects.

Return type `int`

`get_labels`()
Return labels of Attributes within this AttributeStructure.

Returns list of labels of Attribute objects in this AttributeStructure.

Return type `list`

`get_subscripts`()
Return subscripts of Relations within this AttributeStructure.

Returns list of subscripts of Relation objects in this AttributeStructure.

Return type `list`

attribute_system module.

class `attribute_system.`**`AttributeSystem`**(*A*, *objects*)
AttributeSystem class composed of an AttributeStructure and set of objects, i.e.,

$$\mathcal{S} = (\{s_1, \ldots, s_n\}; \mathcal{A})$$

The AttributeSystem class uses the `total_ordering` decorator so strict subsets, supersets and strict supersets are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- ***`attribute_structure`*** – The AttributeStructure of the AttributeSystem.
- **`objects`** – The objects of the AttributeSystem; held as a list of `str`s.
- **`_is_AttributeSystem`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)
Add an Attribute, Relation, AttributeStructure, or AttributeSystem object via the + operator.

Parameters **other** (*Attribute|Relation|AttributeStructure|AttributeSystem*) – The object to combine with the AttributeSystem. An AttributeSystem is always returned regardless of the type of `other` parameter.

Raises

- **TypeError** – `other` parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **ValueError** – Cannot add AttributeSystems with overlapping objects.

__contains__(*key*)
Determine if Attribute, Relation, AttributeStructure, or `str` in `key` parameter is contained by this AttributeSystem via `in` operator.

Parameters **key** (*Attribute|Relation|AttributeStructure|str*) – The key to use when checking for membership.

Raises **TypeError** – `key` must be an Attribute object, Relation object, AttributeStructure object, or `str`.

__deepcopy__(*memo*)
Deepcopy an AttributeSystem object via the `copy.deepcopy` method.

__eq__(*other*)
Determine if two AttributeSystem objects are equal via == operator.

__getitem__(*key*)
Retrieve a reference to the Attribute, Relation, or object in the AttributeSystem via the key provided.

Parameters **key** (*Attribute|Relation|str*) – The Attribute, Relation or name of the object to get the reference of from this AttributeSystem.

Raises **TypeError** – `str` in `key` does not match any object contained in this AttributeSystem.

__iadd__(*other*)
Add an Attribute, Relation, AttributeStructure, or AttributeSystem object via the += operator.

Parameters **other** (*Attribute|Relation|AttributeStructure|AttributeSystem*) – The object to combine with the AttributeSystem. An AttributeSystem is always returned regardless of the type of `other` parameter.

Raises

- **TypeError** – `other` parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **ValueError** – Cannot add AttributeSystems with overlapping objects.

__init__(*A*, *objects*)
Construct AttributeSystem object.

Parameters

- **A** (`AttributeStructure`) – an AttributeStructure object to use as the attribute structure of the AttributeSystem object.
- **objects** (*list*) – A list of `str`s denoting the objects of the AttributeSystem.

Raises

- **TypeError** – `objects` parameter must be a `list` and `A` parameter must be an AttributeStructure object.

- **`ValueError`** – all objects provided in `objects` parameter must be unique non-empty `str`s.

`__isub__`(*other*)
Remove an Attribute, Relation, AttributeStructure, or AttributeSystem object via the `-=` operator. In the case of AttributeStructure and AttributeSystem objects, remove all of their consituent parts from this AttributeSystem.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure|AttributeSystem`*) – The object to remove from the AttributeSystem. An AttributeSystem is always returned regardless of the type of `other` parameter.

Raises

- **`TypeError`** – `other` parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **`ValueError`** – Cannot remove objects not present in this AttributeSystem.

`__le__`(*other*)
Determine if this AttributeSystem is a subset of the AttributeSystem contained in `other` parameter via <= operator.

`__ne__`(*other*)
Determine if two AttributeSystem objects are not equal via != operator.

`__repr__`()
Return a string representation of the AttributeSystem object.

`__str__`()
Return a readable string representation of the AttributeSystem object.

`__sub__`(*other*)
Remove an Attribute, Relation, AttributeStructure, or AttributeSystem object via the − operator. In the case of AttributeStructure and AttributeSystem objects, remove all of their consituent parts from this AttributeSystem.

Parameters **`other`** (*`Attribute|Relation|AttributeStructure|AttributeSystem`*) – The object to remove from the AttributeSystem. An AttributeSystem is always returned regardless of the type of `other` parameter.

Raises

- **`TypeError`** – `other` parameter must be an Attribute, Relation, AttributeStructure, or AttributeSystem object.
- **`ValueError`** – Cannot remove objects not present in this AttributeSystem.

`get_power`()
Get power of this AttributeSystem, i.e., $n \cdot |\mathcal{A}|$.

Returns power of the AttributeSystem: $n \cdot |\mathcal{A}|$

Return type `int`

`is_automorphic`()
Determine if this Attribute System is automorphic.

Returns Whether or not this AttributeSystem is automorphic; i.e., some object is contained by one of the ValueSets of the Attributes.

Return type `bool`

constant_assignemnt module.

class `constant_assignment.`**`ConstantAssignment`**(*vocabulary*, *attribute_system*, *mapping*)

Bases: `assignment.Assignment`

ConstantAssignment class. A ConstantAssignment is a partial function ρ from the constants C of some Vocabulary to the objects $\{s_1, \ldots, s_n\}$ of some AttributeSystem.

The ConstantAssignment class uses the `total_ordering` decorator so strict subsets, supersets and strict supersets are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- ***`vocabulary`*** – a reference to the Vocabulary object the ConstantAssignment is defined over.
- ***`attribute_system`*** – a copy of the AttributeSystem the ConstantAssignment originates from.
- **`mapping`** – The mapping $C \longmapsto \{s_1, \ldots, s_n\}$
- **`source`** – The constants used in the partial mapping ρ.
- **`target`** – The objects used in the partial mapping ρ.
- **`_is_ConstantAssignment`** – An identifier to use in place of type or isinstance.

`__deepcopy__`(*memo*)

Deepcopy a ConstantAssignment object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

`__eq__`(*other*)

Determine if two ConstantAssignment objects are equal via the == operator.

`__getitem__`(*key*)

Retrive the object mapped to the constant given by `key` parameter via indexing (e.g. `ConstantAssignment[key]`).

Parameters **`key`** (*`str`*) – The constant to use for retrieval.

Raises

- **`KeyError`** – constant given by `key` parameter is not in this ConstantAssignment's `source`.
- **`TypeError`** – `key` parameter must be a `str`.

`__init__`(*vocabulary*, *attribute_system*, *mapping*)

Construct a ConstantAssignment object.

Parameters

- **`vocabulary`** (`Vocabulary`) – The Vocabulary the ConstantAssignment is defined over.
- **`attribute_system`** (`AttributeSystem`) – The AttributeSystem from which the objects in the Assignment come from.
- **`mapping`** (`dict`) – The mapping ρ from the constants C of `vocabulary` to the objects $\{s_1, \ldots, s_n\}$ of `attribute_system`.

Raises

- **`TypeError`** – `vocabulary` parameter must be a Vocabulary object, `attribute_system` parameter must be an AttributeSystem object and `mapping` parameter must be a `dict` with `str` keys and values.

- **`ValueError`** – all keys in `mapping` parameter must be in `vocabulary` parameter's constants and all values in `mapping` parameter must be unique and match some object in `attribute_system` parameter.

`__lt__`(*other*)
Overloaded < operator for ConstantAssignment. Determine if this ConstantAssignment is a subset of the ConstantAssignment contained in `other` parameter.

Raises **`TypeError`** – `other` parameter must be a ConstantAssignment object.

`__ne__`(*other*)
Determine if two ConstantAssignment objects are not equal via the `!=` operator.

`__repr__`()
Return a string representation of a ConstantAssignment object.

`__str__`()
Return a readable string representation of a ConstantAssignment object.

`add_mapping`(*constant_symbol*, *obj*)
Extend this ConstantAssignment by adding new mapping from constant in `constant_symbol` parameter to object in `obj` parameter.

Raises

- **`TypeError`** – both `constant_symbol` and `obj` parameters must be `strs`.
- **`ValueError`** – constant in `constant_symbol` parameter must be in `vocabulary` member, object in `obj` parameter must be in the objects of `attribute_system` member and neither the constant nor the object may be a duplicate.

`get_domain`()
Get the set of all and only those constant symbols for which ρ is defined w.r.t. ConstantAssignment's `vocabulary` member.

Returns list of constants for which ρ is defined.

Return type `list`

`in_conflict`(*other*)
Check if this ConstantAssignment is in conflict with ConstantAssignment in `other` parameter.

Returns whether or not this ConstantAssignment and the ConstantAssignment in `other` are in conflict.

Return type `bool`

Raises **`TypeError`** – `other` parameter must be a ConstantAssignment object.

`is_total`()
Determine if this ConstantAssignment is a total function $\widehat{\rho}$ from C $\longrightarrow \{\mathrm{s}_1, \ldots, \mathrm{s}_\mathrm{n}\}$.

Returns whether ot not the source of this ConstantAssignment's mapping covers all of its `vocabulary` member's C.

Return type `bool`

`remove_mapping`(*constant_symbol*, *obj*)
Extend this ConstantAssignment by removing new mapping from constant in `constant_symbol` parameter to object in `obj` parameter.

Raises

- **`TypeError`** – both `constant_symbol` and `obj` parameters must be `strs`.

- **ValueError** – constant in `constant_symbol` parameter must be in `vocabulary` member, object in `obj` parameter must be in the objects of `attribute_system` member and the constant and object must be in the source and target of the mapping respectively.

context module.

class `context.`**`Context`**(*assumption_base*, *named_state*)

Context class. A Context is a pair composed of an AssumptionBase object β and a NamedState object $(\sigma;\rho)$, i.e., $\gamma = (\beta; (\sigma;\rho))$.

Variables

- ***assumption_base*** – The AssumptionBase object β of the Context object.
- ***named_state*** – The NamedState object $(\sigma;\rho)$ of the Context object.
- **is_Context** – An identifier to use in place of type or isinstance.

`__deepcopy__`(*memo*)

Deepcopy a Context object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

`__eq__`(*other*)

Determine if two Context objects are equal via the == operator.

`__init__`(*assumption_base*, *named_state*)

Construct a Context object.

Parameters

- **assumption_base** (`AssumptionBase`) – The AssumptionBase object to use in the Context object.
- **named_state** (`NamedState`) – The NamedState object to use in the Context object.

Raises

- **TypeError** – `assumption_base` parameter must be an AssumptionBase object and `named_state` parameter must be a NamedState object.
- **ValueError** – The underlying Vocabulary objects of the `assumption_base` and `named_state` parameters must be the same Vocabulary object.

`__ne__`(*other*)

Determine if two Context objects are not equal via the $!=$ operator.

`__repr__`()

Return a string representation of the NamedState object.

`__str__`()

Return a readable string representation of the Context object.

`entails_formula`(*formula*, *attribute_interpretation*)

Determine if this Context object entails the Formula object provided by `formula` parameter w.r.t. all worlds and possible variable assignments of this Context, using AttributeInterpretation object provided in `attribute_interpretation` to interpret truth values, i.e., determine if $\gamma \models F$.

Parameters

- **formula** (`Formula`) – The Formula object to check for entailment.
- **attribute_interpretation** (`AttributeInterpretation`) – The AttributeInterpretation to use for the interpretation of truth values during the evauation of the entailment.

Returns Whether or not $\gamma \models F$,that is $(w; \widehat{\rho}) \models_{\chi} \gamma$ implies $(w; \widehat{\rho}) \models_{\chi} F$ for all worlds $(w; \widehat{\rho})$ and variable assignments χ.

Return type `bool`

Raises

- **`TypeError`** – `formula` parameter must be a Formula object and `attribute_interpretation` parameter must be an AttributeInterpretation object.
- **`ValueError`** – This Context and the Formula object provided in the `formula` parameter must share the same underlying Vocabulary object.

`entails_named_state`(*named_state*, *attribute_interpretation*)

Determine if this Context object entails the NamedState object provided by `named_state` parameter w.r.t. all worlds and possible variable assignments of this Context, using AttributeInterpretation object provided in `attribute_interpretation` to interpret truth values, i.e., determine if $\gamma \models (\sigma'; \rho')$.

Parameters

- **`named_state`** (`NamedState`) – The NamedState object to check for entailment.
- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation to use for the interpretation of truth values during the evauation of the entailment.

Returns Whether or not $\gamma \models (\sigma'; \rho')$, that is for all worlds $(w; \widehat{\rho})$ and variable assignments χ, $(w; \widehat{\rho}) \models (\sigma'; \rho')$ whenever $(w; \widehat{\rho}) \models_{\chi} \gamma$.

Return type `bool`

Raises

- **`TypeError`** – `named_state` parameter must be a NamedState object and `attribute_interpretation` parameter must be an AttributeInterpretation object.
- **`ValueError`** – This Context and the NamedState object provided in the `formula` parameter must share the same underlying Vocabulary object.

formula module.

class `formula.`**`Formula`**(*vocabulary*, *name*, **terms*)

Formula class. Formula objects are defined over some Vocabulary Σ. Formula objects are immutable.

Variables

- ***`vocabulary`*** – The underlying Vocabulary object the Formula is defined over.
- **`name`** – The name of the Formula object.
- **`terms`** – The terms of the Formula object.
- **`is_Formula`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)

Combine A formula and another Formula or AssumptionBase into an AssumptionBase via the + operator.

Raises

- **`TypeError`** – Only a Formula object or AssumptionBase object can be combined with a Formula object.
- **`ValueError`** – This Formula and `other` parameter must share the same Vocabulary object and duplicate Formula objects are not permitted (determined by name of the Formula object only).

__deepcopy__(*memo*)
Deepcopy a Formula object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

__eq__(*other*)
Determine if two Formula objects are equal via the == operator.

__hash__()
Hash implementation for set functionality of Formula objects.

__init__(*vocabulary*, *name*, **terms*)
Construct a Formula object.

Parameters

- **vocabulary** (`Vocabulary`) – The underlying Vocabulary object the Formula will be defined over.
- **name** (`str`) – The name (identifier) of the formula.
- **terms** (`str`) – Any amount of `str` constants and variables representing the terms of the formula.

Raises

- **TypeError** – `vocabulary` parameter must be a Vocabulary object.
- **ValueError** – `name` parameter must matcg some RelationSymbol object in the `vocabulary` parameter, at least one term must be provided and all terms provided must be in either the constants or variables of the `vocabulary` parameter.

__ne__(*other*)
Determine if two Formula objects are not equal via the `!=` operator.

__repr__()
Return a string representation of the NamedState object in the following form: F$(t_1, \ldots, t_n)$ where *n* is the number of terms in the formula.

__str__()
Return a readable string representation of the NamedState object in the following form: F$(t_1, \ldots, t_n)$ where *n* is the number of terms in the formula.

_key()
Private key function for hashing.

Returns tuple consisting of (name, $t_1, \ldots, t_n$)

Return type `tuple`

assign_truth_value(*attribute_interpretation*, *named_state*, *X*)
Assign a truth value in {true, false, unknown} to this Formula w.r.t. an AttributeInterpretation object given an arbitrary NamedState object in `named_state` parameter and VariableAssignment object in `X` parameter.

This function makes use of the ParserSet object; the ParserSet object is a key part in the vivid object extension protocol.

The assign_truth_value function works as follows:

1. Find the entry in the interpretation table of the AttributeInterpretation object in the `attribute_interpretation` parameter and extract the corresponding profile and Relation object (the 3rd element of the corresponding row of the table is the identifier for the Relation object; e.g. $R_{subscript}$).

2. Substitute the terms of the Formula into the profile (the 2nd element of each pair in the profile corresponds to the index of the term in the Formula to use, shifted down by 1).

3. Using the ConstantAssignment object of the `named_state` parameter ρ and the VariableAssignment in the `X` parameter χ, substitute for each term now in the profile, the object corresponding to that term given by the mapping in ρ or χ (if the term is in neither ρ nor χ, "unknown" is returned as the truth value).

4. The profile now consists of the attribute-object pairs to use in the Relation object's definition when creating the evaluatable expression. Now, all worlds derivable from the NamedState are generated and the ValueSets of the attribute-object pairs in the profile (consisting of single elements) are extracted from the ascriptions of these worlds.

5. The single element ValueSets are zipped together with the arguments in the Relation object definition (the ith attribute-object pair of the profile is zipped with the ith argument of the definition) and these new argument-ValueSet pairs are used to substitute every occurance of each argument in the definition with the corresponding single element ValueSet creating a (hopefully) evaluatable expression (the RHS of the substituted definition) for each world.

6. Each parser in the ParserSet object will then try to evaluate the expression and save the truth value for each world. If some expression is unevaluatable for all parsers in the ParserSet a ValueError is raised.

7. If the expression of every world evaluates to true, the truth value returned is `true`, if the expression of every world evaluates to false, the truth value returned is `false` and if the expressions of any two worlds evaluate to different values, the truth value returned is `unknown`.

Returns A truth value in the set {true, false, unknown}

Return type `bool|str`

Raises

- **`TypeError`** – `attribute_interpretation` parameter must be an AttributeInterpretation object, `named_state` parameter must be a NamedState object and `X` parameter must be a VariableAssignment object.
- **`ValueError`** – This Formula object, the AttributeInterpretation object in the `attribute_interpretation` parameter, the NamedState object in the `named_state` parameter and the VariableAssignment object in the `X` parameter must all share the same underlying Vocabulary object, the Formula object must match an entry in the interpretation table of the `attribute_interpretation` parameter, the number of attribute-object pairs in the profile corresponding to the Formula must match the arity of the corresponding Relation object found in the table (where the Relation object is found in the AttributeStructure object in the AttributeSystem member of the `named_state` parameter), $1 \leq j_x \leq n$ for each j_x in the profile (where *n* is the arity of the RelationSymbol corresponding to the RelationSymbol object matching the Formula in the interpretation table, or equivalently, the number of terms in the Formula object) and a parser in the ParserSet object must be able to evaluate the expression obtained after substituting the objects of the AttributeSystem in the `named_state` parameter, corresponding to the terms of the Formula, into the Relation object's definition.

static `get_basis` (*constant_assignment*, *variable_assignment*, *attribute_interpretation*, **formulae*)

Get the basis of the formula objects provided in optional positional arguments `formulae` parameter w.r.t. a the ConstantAssignment object provided in `constant_assignment` parameter, VariableAssignment object provided in `variable_assignment` parameter, and AttributeInterpretation object provided in `attribute_interpretation` parameter, i.e., compute the union of $\mathcal{B}(F, \rho, \chi)$ for each Formula object.

Parameters

- **`constant_assignment`** (`ConstantAssignment`) – The ConstantAssignment object to use to compile the profile corresponding to each Formula object into attribute-object pairs to consider for the basis.
- **`variable_assignment`** (VariableAssignment | `None`) – The VariableAssignment object to use to compile the profile corresponding to each Formula object into attribute-object pairs to consider for the basis or `None`.
- **`attribute_interpretation`** (`AttributeInterpretation`) – The AttributeInterpretation object to use to determine the profiles corresponding to the Formula objects provided (the profile is extracted from the interpretation table when the RelationSymbol matching the Formula object's name is found).
- **`formulae`** (`Formula`) – Any positive amount of Formula objects to consider in the basis.

Returns A list of attribute-object pairs comprising the basis of the Formula objects provided w.r.t. ρ and χ.

Return type `list`

Raises

- **`TypeError`** – `constant_assignment` parameter must be a ConstantAssignment object, and all optional positional arguments provided in `formulae` parameter must be Formula objects.
- **`ValueError`** – At least one Formula object must be provided and all Formula objects provided must match some entry in the interpretation table of the AttributeInterpretation object.

interval module.

class `interval.`**`Interval`**(*inf*, *sup*)

Class to represent an interval of natural or real values.

Variables

- **`infimum`** – The infimum of the interval.
- **`supremum`** – The supremum of the interval.
- **`type`** – The type of the Interval object (int, float, or long).
- **`_is_Interval`** – An identifier to use in place of type or isinstance.

`__and__`(*other*)

Overloaded `&` operator; return the intersection of two Interval objects.

Raises **`ValueError`** – Intervals must overlap to take the intersection.

`__contains__`(*key*)

Determine if this Interval contains an int, float, long, or another Interval.

Parameters **`key`** (*`int | float | long | Interval`*) – The value to check for membership in this Interval.

`__deepcopy__`(*memo*)

Deepcopy an Interval object via the `copy.deepcopy` method.

`__eq__`(*other*)

Determine if two Interval objects are equal via the == operator.

`__ge__`(*other*)
Overloaded >= operator for Interval. Determine if an Interval is greater than another Interval; that is the infimum of the Interval in `other` parameter is strictly less than this Interval's infimum, and the supremum of the interval in `other` parameter is less than this Interval's supremum: (o_{inf}, (s_{inf}, o_{sup}), s_{sup}).

`__getitem__`(*index*)
Retrieve the infimum or supremum of the Interval via indexing (e.g. `Interval[0]`).

Raises

- **`IndexError`** – Index must be either `0` or `1`.
- **`TypeError`** – Index must be an int.

`__gt__`(*other*)
Overloaded > operator for Interval. Determine if an Interval is strictly greater than another interval; that is the infimum of this Interval is strictly greater than the supremum of the Interval in `other` parameter: (o_{inf}, o_{sup})(s_{inf}, s_{sup}).

`__hash__`()
Hash implementation for set functionality of Interval objects.

`__init__`(*inf, sup*)
Construct an Interval object.

Parameters

- **`inf`** (*`int | float | long`*) – The value to use as the infimum of the Interval.
- **`sup`** (*`int | float | long`*) – The value to use as the supremum of the Interval.

Raises

- **`ValueError`** – infimum must be strictly less than the supremum.
- **`TypeError`** – infimum and supremum provided must be ints, floats, or longs and their types must match.

`__le__`(*other*)
Overloaded <= operator for Interval. Determine if an Interval is less than another Interval; that is the supremum of this Interval is greater than the Interval in `other`'s infimum, less than the Interval in `other`'s supremum and the infimum of this Interval is strictly less than the infimum of the Interval in `other` parameter: (s_{inf}, (o_{inf}, s_{sup}), o_{sup}).

`__lt__`(*other*)
Overloaded < operator for Interval. Determine if an Interval is strictly less than another interval; that is the supremum of this Interval is strictly less than the infimum of the Interval in `other` parameter: (s_{inf}, s_{sup})(o_{inf}, o_{sup}).

`__ne__`(*other*)
Determine if two Interval objects are not equal via the `!=` operator.

`__or__`(*other*)
Overloaded `|` operator; return the union of two Interval objects.

Raises **`ValueError`** – Intervals must overlap to take the union.

`__repr__`()
Return a string representation of an Interval object with the following form: "I(*infimum*, *supremum*)"

`__str__`()
Return a readable string representation of an Interval object with the following form: "I(*infimum*, *supremum*)"

_key()
Private key function for hashing.

Returns 2-tuple consisting of (infimum, supremum)

Return type `tuple`

static collapse_intervals(*intervals*)
Collapse a set of overlapping intervals.

Parameters **intervals** (*list*) – A list of intervals to collapse.

Returns A new list totally disjoint collapsed Intervals.

Return type `list`

discretize(*jump=None*)
Return all values within the range of this interval.

Parameters **jump** (*None | int | float | long*) – The jump to use after each value. Defaults to `1`, `1.0` and `1` for int, float, and long Intervals respectively.

Returns list of discrete values contained in this Interval with a step size of `jump`.

Return type `list`

Raises **TypeError** – if a jump is provided, it must be an int, float, or long and match the type of this Interval.

named_state module.

class named_state.**NamedState**(*attribute_system*, *p*, *ascriptions={}*)
Bases: *state.State*

NamedState class. Each state is a pair $(\sigma; \rho)$ consisting of a state σ and a constant assignment ρ.

The NamedState class uses the `total_ordering` decorator so proper extensions, contravariant extensions and contravariant proper extensions are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- ***attribute_system*** – A copy of the AttributeSytem object that the NamedState object comes from.
- **ascriptions** – The ascriptions of the named state, i.e., (the set of attribute-object pairs and their corresponding ValueSet objects)
- **p** – The ConstantAssignment object of the named state.
- **_is_NamedState** – An identifier to use in place of type or isinstance.

__deepcopy__(*memo*)
Deepcopy a NamedState object via the `copy.deepcopy` method. This does not break the reference to the underlying Vocabulary object.

__eq__(*other*)
Determine if two NamedState objects are equal via the == operator.

__init__(*attribute_system*, *p*, *ascriptions={}*)
Construct a NamedState object.

Parameters

- **attribute_system** (`AttributeSystem`) – The AttributeSystem object from which the NamedState comes from.

- **p** (ConstantAssignment) – The ConstantAssignment object of the named state.
- **ascriptions** (dict) – An optional dictionary of attribute-object pairs to use as ascriptions; if some attribute-object pair is not provided, the full ValueSet of the Attribute object corresponding to the attribute label in the attribute-object pair is used.

Raises

- **TypeError** – p parameter must be a ConstantAssignment object.
- **ValueError** – The AttributeSystem object provided and the ConstantAssignment p parameter's AttributeSystem must match.

__le__(*other*)
Overloaded <= operator for NamedState; Determine if this State is an extension of NamedState object in `other` parameter.

Raises TypeError – `other` parameter must be a NamedState object.

__ne__(*other*)
Determine if two NamedState objects are not equal via the != operator.

__repr__()
Return a string representation of the State object.

__str__()
Return a readable string representation of the NamedState object.

_generate_variable_assignments()
Generate all possible VariableAssignment objects derivable from this NamedState i.e., find all combinations of unbound objects and variables in the underlying Vocabulary object (a reference to it is held by the NamedState's ConstantAssignment). If no VariableAssignments can be created, a dummy VariableAssignment is returned.

Returns A generator for all derivable VariableAssignment objects.

Return type generator

add_object(*obj*, *ascriptions=None*, *constant_symbol=None*)
Add an object to this NamedState's AttributeSystem, optionally update any ascriptions provided and optionally bind it to a constant given by `constant_symbol` (if the constant does not exist in the underlying Vocabulary object, it will be added to the Vocabulary object and furthermore all objects holding a reference to the Vocabulary will receive the update).

Parameters

- **obj** (str) – The new object to add to the NamedState.
- **ascriptions** (dict) – The optional ValueSets to assign to attribute-object pairs corresponding to the new object.
- **constant_symbol** (str) – The optional constant to bind to the new object.

Raises

- **TypeError** – `obj` parameter must be a non-empty `str`, if `ascriptions` parameter is provided, it must be a `dict` and `constant_symbol` parameter must be a `str`.
- **ValueError** – Duplicate objects cannot be added, constant corresponding to `constant_symbol` cannot be bound already and all ascriptions provided must be from an existing Attribute to `obj` parameter.

get_alternate_extensions(**states*)
Return all alternate extensions of this State object with respect to states provided by optional positional arguments of `states` parameter, i.e., generate $\mathbf{AE}(\{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Parameters **states** (`State`) – The states $\{\sigma_1, \ldots, \sigma_\mathrm{m}\}$ to use for the derivation of the alternate extensions of this State.

Returns $\mathbf{AE}(\{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Return type `list`

Raises

- **TypeError** – all optional positional arguments must be State objects.
- **ValueError** – at least one State object must be provided in optional positional arguments and all provided State objects must be proper extensions of this State object.

get_named_alternate_extensions(**named_states*)
Obtain all alternate extensions of this NamedState w.r.t. NamedState objects provided in `named_states` parameter, i.e., compute $\mathbf{AE}(\Sigma_i, \sigma)$ for the various applicable *i* according to algorithm.

Returns all alternative extensions of this NamedState object $(\sigma; \rho)$ w.r.t. $(\sigma_1;\rho_1), \ldots, (\sigma_m;\rho_m)$ provided as optional positional arguments in `named_states` parameter.

Return type `list`

Raises

- **TypeError** – `ns_prime` and all arguments provided to optional positional arguments `named_states` must be NamedState objects.
- **ValueError** – At least one NamedState object must be provided in `named_states` parameter and all NamedState objects in `ns_prime` and `named_states` parameters must be proper extensions of this NamedState.

get_worlds()
Return a generator for the generation of all possible worlds derivable from this NamedState object.

Returns A generator for the generation of all possible worlds derivable from this NamedState object.

Return type `generator`

is_alternate_extension(*s_prime*, **states*)
Determine if `s_prime` parameter is an alternate extension of this State object w.r.t. states provided by optional positional arguments of `states` parameter, i.e., evaluate *Alt*$(\sigma, \{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Parameters

- **s_prime** (`State`) – The State object to verify as the alternate extension, σ'
- **states** (`State`) – The states $\{\sigma_1, \ldots, \sigma_\mathrm{m}\}$ to use for the derivation of the alternate extensions of this State.

Returns the result of the evaluate of *Alt*$(\sigma, \{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Return type `bool`

Raises **TypeError** – `s_prime` parameter must be a State object.

is_disjoint(*other*)
Determine if this State is disjoint from the State in `other` parameter.

Returns Whether or not this State object and State object contained in `other` parameter are disjoint.

Return type `bool`

is_exhaustive(*basis*, **named_states*)

Determine if on some basis, a set of NamedState objects is exhaustive w.r.t this NamedState.

Parameters

- **basis** (`list`) – A list of attribute-object pairs (`str`, `str` 2-tuples).
- **named_states** (`NamedState`) – Any positive amount of NamedState objects.

Returns Whether or not the NamedState objects provided as optional positional arguments are exhaustive w.r.t. this NamedState object on the basis provided in `basis` parameter.

Return type `bool`

Raises **ValueError** – `basis` parameter cannot be empty and at least one NamedState object must be provided.

is_named_alternate_extension(*ns_prime*, **named_states*)

Determine if `ns_prime` parameter is an alternate extension of this NamedState w.r.t. NamedState objects provided in `named_states` parameter, i.e., evaluate *Alt*((σ; ρ), {(σ_1;ρ_1), . . . , (σ_m;ρ_m)}, (σ'; ρ')).

Returns The result of the evaluation of *Alt*((σ; ρ), {(σ_1;ρ_1), . . . , (σ_m;ρ_m)}, (σ'; ρ')).

Return type `bool`

Raises

- **TypeError** – `ns_prime` and all arguments provided to optional positional arguments `named_states` must be NamedState objects.
- **ValueError** – At least one NamedState object must be provided in `named_states` parameter and all NamedState objects in `ns_prime` and `named_states` parameters must be proper extensions of this NamedState.

is_named_entailment(*assumption_base*, *attribute_interpretation*, **named_states*)

Determine if this NamedState object entails NamedState objects provided as optional positional arguments to `named_states` parameter w.r.t. the AssumptionBase object in the `assumption_base` parameter, using the AttributeInterpretation object provided in the `attribute_interpretation` parameter to resolve truth values of the Formula objects contained therein, i.e., $(\sigma;\rho) \Vdash_\beta \{(\sigma_1;\rho_1),\ldots,(\sigma_m;\rho_m)\}$.

Parameters

- **assumption_base** (`AssumptionBase`) – The AssumptionBase object to use when evaluating $I_{(\sigma';\rho')/\chi}\left(\bigwedge_{F\,\in\,\beta} F\right) = \textbf{false}$ for all χ.
- **attribute_interpretation** (`AttributeInterpretation`) – The AttributeInterpretation object to use to resolve the truth values of Formula objects in the AssumptionBase object in `assumption_base` parameter.
- **named_states** (`NamedState`) – Any amount of NamedState objects $(\sigma_1;\rho_1),\ldots,(\sigma_m;\rho_m)$ to check for entailment.

Returns Whether or not $(\sigma;\rho) \Vdash_\beta \{(\sigma_1;\rho_1),\ldots,(\sigma_m;\rho_m)\}$

Return type `bool`

Raises

- **TypeError** – `assumption_base` parameter must be an AssumptionBase, `attribute_interpretation` parameter must be an AttributeInterpretation object, and all optional positional arguments in `named_states` parameter must be NamedState objects.

- **ValueError** – all NamedState objects provided as optional positional arguments to `named_states` parameter must share the same Vocabulary object, AttributeSystem object and be proper extensions of this NamedState object.

is_valuation(*label*)

Determine if ascription δ_i corresponding to `label` parameter is a valuation; that is $|\delta_i(s_j)| = 1$ for every $j = 1, \ldots, n$.

Parameters **label** (`str`) – The label corresponding to the δ_i to check for valuation.

Returns whether or not ascription corresponding to `label` is a valuation.

Return type `bool`

is_world()

Determine if this NamedState object is a world; that is σ is a world (every ascription of σ is a valuation) and ρ is total.

Returns Whether or not the NamedState is a world.

Return type `bool`

join(*s1*, *s2*)

Join two states if possible.

Parameters

- **s1** (`State`) – The left operand to use for the union operation.
- **s2** (`State`) – The right operand to use for the union operation.

Raises **ValueError** – `s1` and `s2` parameters must share the same underlying AttributeSystem.

satisfies_context(*context*, *X*, *attribute_interpretation*)

Determine if this NamedState object $(w; \widehat{\rho})$ (which must be a world) satisfies given context $\gamma = (\beta; (\sigma; \rho))$ w.r.t. a given VariableAssignment χ and given AttributeInterpretation, i.e., $(w; \widehat{\rho}) \models_\chi \gamma$ (this NamedState object satisfies every Formula object in the AssumptionBase object of the Context object and this NamedState object satisfies the NamedState object of the Context object).

Parameters

- **context** (`Context`) – The context γ to check for satisfaction.
- **X** (`VariableAssignment`) – The variable assignment χ
- **attribute_interpretation** (`AttributeInterpretation`) – The fixed attribute interpretation to use for interpreting which constants and variables get substituted into the formula for evaluation.

Returns whether or not $(w; \widehat{\rho}) \models_\chi \gamma$.

Return type `bool`

Raises

- **TypeError** – `context` parameter must be a Context object, `X` parameter must be a VariableAssignment object and `attribute_interpretation` must be an AttributeInterpretation object.
- **ValueError** – This NamedState object must be a world.

satisfies_formula(*formula*, *X*, *attribute_interpretation*)

Determine if this NamedState object $(w; \widehat{\rho})$ (which must be a world) satisfies given formula F w.r.t. VariableAssignment χ and given AttributeInterpretation, i.e., $(w; \widehat{\rho}) \models_\chi F$.

Parameters

- **formula** (`Formula`) – The formula F to check for satisfaction.
- **X** (`VariableAssignment`) – The variable assignment χ
- **attribute_interpretation** (`AttributeInterpretation`) – The fixed attribute interpretation to use for interpreting which constants and variables get substituted into the formula for evaluation.

Returns whether or not $(w;\widehat{\rho}) \models_{\chi} F$.

Return type `bool`

Raises

- **TypeError** – `formula` parameter must be a Formula object, `X` parameter must be a VariableAssignment object and `attribute_interpretation` must be an AttributeInterpretation object.
- **ValueError** – this NamedState object must be a world.

satisfies_named_state(*named_state*)

Determine if this NamedState object $(w;\widehat{\rho})$ (which must be a world) satisfies given NamedState object $(\sigma;\rho)$ i.e., $(w;\widehat{\rho}) \models (\sigma;\rho)$.

Parameters **named_state** (`NamedState`) – The named state $(\sigma;\rho)$ to check for satisfaction.

Returns Whether or not $(w;\widehat{\rho}) \models (\sigma;\rho)$.

Return type `bool`

Raises

- **TypeError** – `named_state` parameter must be a NamedState object.
- **ValueError** – this NamedState object must be a world.

set_ascription(*ao_pair*, *new_valueset*)

Set an ascription, given by `ao_pair` parameter, of this State object to the ValueSet object provided in `new_valueset` parameter.

Parameters

- **ao_pair** (`tuple`) – The attribute-object pair to use as a key for the ascription `dict` member.
- **new_valueset** (`ValueSet`) – The new ValueSet object to assign to the corresponding attribute-object pair given by the `ao_pair` paramater in the ascription member

Raises

- **TypeError** – `ao_pair` parameter must be a `tuple` and `new_valueset` parameter must be a `list`, `set`, or ValueSet object.
- **ValueError** – `ao_pair` parameter must be a 2-tuple (`str`,`str`) and `new_valueset` parameter must be a non-empty subset of the ValueSet object of the Attribute object corresponding to the attribute in the `ao_pair` parameter.
- **KeyError** – `ao_pair` must be a key in `ascriptions` member of this State object.

point module.

class `point.`**Point**(**coordinates*)

Class to represent a point of N_d cartesian space.

Point objects are immutable.

Variables

- **`is_generic`** – whether or not the Point is generic (i.e., the coordinates have not been defined).
- **`coordinate`** – the coordinate of the Point object.
- **`dimension`** – the dimension of space the Point object exists in.
- **`_is_Point`** – An identifier to use in place of type or isinstance.

`__deepcopy__`(*memo*)
Deepcopy a Point object via the `copy.deepcopy` method.

`__eq__`(*other*)
Determine if two Point objects are equal via the == operator.

`__getitem__`(*key*)
Retrieve the ith cooridinate from a Point object via indexing (e.g., `Point[i]`).

Raises

- **`TypeError`** – key parameter must be an int.
- **`IndexError`** – key must be within the set {0, . . . ,d}.

`__hash__`()
Hash implementation for set functionality of Point objects.

`__init__`(**coordinates*)
Construct a Point object.

Parameters **`coordinates`** (*`strs|floats`*) – The values to use as the coordinates of the Point object. At least one coordinate must be provided; to create a generic point object, pass values of "x".

Raises

- **`ValueError`** – At least one coordinate must be provided.
- **`TypeError`** – All cooridnates must be either strings

(equal to "x") or floats.

`__ne__`(*other*)
Determine if two Point objects are not equal via the `!=` operator.

`__repr__`()
Return a string representation of a Point object with the following form: "P(c_1, . . . ,c_d)".

`__str__`()
Return a readable string representation of a Point object with the following form: "P(c_1, . . . ,c_d)".

`_key`()
Private key function for hashing.

Returns d-tuple consisting of coordinates

Return type tuple

`can_observe`(*spacetime_loc*, *worldline_start*, *worldline_end*)
Determine if this Point can observe the spacetime location represented by Point `spacetime_loc` on the worldline segment determined by the `worldline_start` and `worldline_end` Points.

Raises **`ValueError`** – The Point and the worldine endpoints must all be in the same dimension of space and no point involved can be generic.

Returns whether or not this Point can observe `spacetime_loc` through worldline defined by `worldline_start` and `worldline_end`.

Return type `bool`

`clocks_unequal`(*other*)
Determine if the clocks of two spacetime locations are unequal wherein the last coordinate of represents time.

Returns whether or not this Point's last coordinate is equal to the last coordinate of the Point in `other`.

Return type `bool`

Raises **`ValueError`** – Dimensions of Point contained in other parameter and this Point must match.

`is_on`(*endpoint_1*, *endpoint_2*)
Determine if this Point object lies on line segment defined by the endpoint Point objects provided in the `endpoint_1` and `endpoint_2` parameters.

Raises **`ValueError`** – The Point and the endpoints must all be in the same dimension of space and no point involved can be generic.

Returns whether or not this Point lies on line segment.

Return type `bool`

`meets`(*worldline_1_start*, *worldline_1_end*, *worldline_2_start*, *worldline_2_end*)
Determine if the worldline segments defined by the `worldline_1_start` and `worldline_1_end` Points and the `worldline_2_start` and `worldline_2_end` Points meet at this Point object's coordinates.

Returns whether or not worldines meet at this Point's coordinates.

Return type `bool`

Raises **`ValueError`** – The Point and the worldine endpoints must all be in the same dimension of space and no point involved can be generic.

`not_same_point`(*other*)
Determine if this Point and Point contained in `other` parameter are the same.

Returns whether or not this Point is equal to Point in `other`.

Return type `bool`

static `unstringify`(*point_string*)
Reconstruct a Point object from its string representation.

Returns Point object reconstructed from string representation.

Return type *Point*

Raises **`ValueError`** – The string must match the form given by `str(Point)` or `repr(Point)`, i.e., "P(c_1, . . . ,c_d)"

relation module.

class `relation.`**`Relation`**(*definition*, *D_of_r*, *subscript*)
Class to represent logical relations used in AttributeStructure objects.

Variables

- **`definition`** – string representation of definition with form `Rn(a,...) <=> ...` where n is a positive integer; whitespace is ignored.

- **`DR`** – DR represents $D(R) \subseteq \{A_1, \ldots, A_n\}$; held as a list of strings corresponding to labels of some set of Attributes objects; no assumptions are made on the labels of the attributes.
- **`subscript`** – subscript of relation.

`__add__`(*other*)
Combine a Relation object with an Attribute object, an AttributeStructure object or an AttributeSystem object via the + operator.

Parameters **`other`** (*`Attribute|AttributeStructure|AttributeSystem`*) – The object to combine with the Attribute. If an Attribute or AttributeStructure object is provided, an AttributeStructure object is returned; if an AttributeSystem object is provided, an AttributeSystem is returned.

Raises **`TypeError`** – other parameter must be an Attribute, AttributeStructure, or AttributeSystem object.

`__deepcopy__`(*memo*)
Deepcopy a Relation object via the `copy.deepcopy` method.

`__eq__`(*other*)
Determine if two Relation objects are equal via the == operator.

`__init__`(*definition*, *D_of_r*, *subscript*)
Construct a Relation object.

Parameters

- **`definition`** (*`str`*) – The definition of the logical relation; valid definitions have the form: `Rn(a,...)  <=> ....`
- **`D_of_r`** (*`list`*) – $D(R) \subseteq \{A_1, \ldots, A_n\}$; a list of strings.
- **`subscript`** (*`int`*) – The subscript of the relation; must match subscript in definition.

Raises

- **`TypeError`** – definition must be a `str`, D_of_r must be a `list` of containing only `str`s and subscript must be an `int`.
- **`ValueError`** – definition must be in correct form, number of parameter provided in `definition` must match the length of `D_of_r` and `subscript` must match subscript provided in `definition`.

`__ne__`(*other*)
Determine if two Relation objects are not equal via the `!=` operator.

`__repr__`()
"Return a string representation of a Relation object.

`__str__`()
Return a readable string representation of a Relation object.

`get_DR`(*string=False*)
Return $D(R)$ of relation. If string is set to True, return string representation of $D(R)$.

Parameters **`string`** (*`boolean`*) – boolean for whether or not to return string representation of $D(R)$

Returns A representation of $D(R)$

Return type `str` or `list`

`get_arity`()
Return arity of this Relation object.

Returns length of *D*(*R*).

Return type `int`

static `is_valid_definition`(*definition*)

Determine if a given definition is valid. A definition is valid when it is of the form `Rs(x1,...,xn)` <=> <expression>. The important thing here is the left hand side and the marker '<=>'. Everything on the right hand side of '<=>' is ignored as far as Relation definition is concerned; whether or not it is evaluatable is left to `Formula.assign_truth_value()` as it is only during the assignment of a truth value that the expression comes into play. All whitespace is trimmed immediately so arbitrary spacing is allowed.

Parameters **`definition`** (*`str`*) – The definition to verify.

Returns whether or not `definition` is valid.

Return type `bool`

`set_DR`(*DR*)

Set *D*(*R*).

Parameters **`DR`** (*`list`*) – The list of strings to set this Relation object's *D*(*R*) to.

Raises

- **`TypeError`** – *D*(*R*) is not a `list` of `str`s.
- **`ValueError`** – *D*(*R*) cardinality must match argument cardinality in Relation object's definition.

`set_definition`(*definition*)

Set definition; ensure that it conforms to required format.

Parameters **`definition`** (*`str`*) – The new definition of the Relation object.

Raises

- **`TypeError`** – `definition` parameter must be a `str`.
- **`ValueError`** – `definition` must conform to valid definition rules.

relation_symbol module.

class `relation_symbol.`**`RelationSymbol`**(*name*, *arity*)

Relation Symbols class for Vocabularies.

Variables

- **`name`** – a `str` designating the name of the RelationSymbol object.
- **`arity`** – an `int` designating the arity of the RelationSymbol object.

`__deepcopy__`(*memo*)

Deepcopy a RelationSymbol object via the `copy.deepcopy` method.

`__eq__`(*other*)

Determine if two RelationSymbol objects are equal via the == operator.

`__hash__`()

Hash implementation for set functionality of RelationSymbol objects.

`__init__`(*name*, *arity*)

Construct a RelationSymbol object.

Parameters

- **`name`** (`str`) – The name of the RelationSymbol object.

- **arity** (int) – The arity of the RelationSymbol object.

Raises

- **TypeError** – name parameter must be a str and arity parameter must be an int.
- **ValueError** – arity must be positive.

__ne__(*other*)
Determine if two RelationSymbol objects are not equal via the != operator.

__repr__()
Return a string representation of a RelationSymbol object.

__str__()
Return a readable string representation of a RelationSymbol object.

_key()
Private key function for hashing.

Returns 2-tuple consisting of (name, arity)

Return type tuple

state module.

class state.**State**(*attribute_system*, *ascriptions={}*)
State class. Each State object is a state of an AttributeSystem; that is a set of functions $\sigma = \{\delta_1, \ldots, \delta_k\}$ where each δ_i is a function from $\{s_1, \ldots, s_n\}$ to the set of all non-empty finite subsets of A_i, i.e.,

$$\delta_i : \{s_1, \ldots, s_n\} \to \mathcal{P}_{fin}(A_i)\backslash\emptyset.$$

The State class uses the total_ordering decorator so proper extensions, contravariant extensions and contravariant proper extensions are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- ***attribute_system*** – A copy of the AttributeSytem object that the State object comes from.
- **ascriptions** – The ascriptions of the state, i.e., (the set of attribute-object pairs and their corresponding ValueSet objects)
- **_is_State** – An identifier to use in place of type or isinstance.

__deepcopy__(*memo*)
Deepcopy a State object via the copy.deepcopy method.

__eq__(*other*)
Determine if two State objects are equal via the == operator.

__getitem__(*key*)
Retrive the ascription or ValueSet corresponding to the attribute-object pair given by key parameter via indexing (e.g. State[key]).

Raises

- **KeyError** – key parameter must be a valid Attribute label or valid attribute-object pair in the underlying AttributeSystem of the State object.
- **TypeError** – key parameter must be a str or tuple containing only strs.

__init__(*attribute_system*, *ascriptions={}*)
Construct a State object.

Parameters

- **attribute_system** (AttributeSystem) – The AttributeSystem object from which the State comes from.
- **ascriptions** (dict) – An optional dictionary of attribute-object pairs to use as ascriptions; if some attribute-object pair is not provided, the full ValueSet of the Attribute object corresponding to the attribute label in the attribute-object pair is used.

Raises **TypeError** – `attribute_system` parameter must be an AttributeSystem object and `ascriptions` parameter must be a `dict`.

__le__(*other*)
Overloaded <= operator for State; Determine if this State is an extension of State object in `other` parameter.

Raises

- **TypeError** – `other` parameter must be a State object.
- **ValueError** – State object in `other` parameter must share the same AttributeSystem object as this State object.

__ne__(*other*)
Determine if two State objects are not equal via the != operator.

__repr__()
Return a string representation of the State object.

__str__()
Return a readable string representation of the State object.

add_object(*obj*, *ascriptions=None*)
Add an object to this State's AttributeSystem and optionally update any ascriptions provided.

Parameters

- **obj** (str) – The new object to add to the State.
- **ascriptions** (dict) – The optional ValueSets to assign to attribute-object pairs corresponding to the new object.

Raises

- **TypeError** – `obj` parameter must be a non-empty `str` and if `ascriptions` parameter is provided, it must be a `dict`.
- **ValueError** – Duplicate objects cannot be added and all ascriptions provided must be from an existing Attribute to `obj` parameter.

get_alternate_extensions(**states*)
Return all alternate extensions of this State object with respect to states provided by optional positional arguments of `states` parameter, i.e., generate $\mathbf{AE}(\{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Parameters **states** (State) – The states $\{\sigma_1, \ldots, \sigma_\mathrm{m}\}$ to use for the derivation of the alternate extensions of this State.

Returns $\mathbf{AE}(\{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Return type `list`

Raises

- **TypeError** – all optional positional arguments must be State objects.

- **ValueError** – at least one State object must be provided in optional positional arguments and all provided State objects must be proper extensions of this State object.

get_worlds()

Return a list of all possible worlds derivable from this State object.

Returns all worlds derivable from this State object.

Return type list

is_alternate_extension(*s_prime*, **states*)

Determine if s_prime parameter is an alternate extension of this State object w.r.t. states provided by optional positional arguments of states parameter, i.e., evaluate *Alt*$(\sigma, \{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Parameters

- **s_prime** (State) – The State object to verify as the alternate extension, σ'
- **states** (State) – The states $\{\sigma_1, \ldots, \sigma_m\}$ to use for the derivation of the alternate extensions of this State.

Returns the result of the evaluate of *Alt*$(\sigma, \{\sigma_1, \ldots, \sigma_m\}, \sigma')$.

Return type bool

Raises TypeError – s_prime parameter must be a State object.

is_disjoint(*other*)

Determine if this State is disjoint from the State in other parameter.

Returns Whether or not this State object and State object contained in other parameter are disjoint.

Return type bool

is_valuation(*label*)

Determine if ascription δ_i corresponding to label parameter is a valuation; that is $|\delta_i(s_j)|= 1$ for every $j = 1, \ldots, n$.

Parameters label (str) – The label corresponding to the δ_i to check for valuation.

Returns whether or not ascription corresponding to label is a valuation.

Return type bool

is_world()

Determine if this State is a world; that is every ascription of this σ is a valuation.

Returns Whether or not the State is a world.

Return type bool

static join(*s1*, *s2*)

Join two states if possible.

Parameters

- **s1** (State) – The left operand to use for the union operation.
- **s2** (State) – The right operand to use for the union operation.

Raises ValueError – s1 and s2 parameters must share the same underlying AttributeSystem.

set_ascription(*ao_pair*, *new_valueset*)

Set an ascription, given by ao_pair parameter, of this State object to the ValueSet object provided in new_valueset parameter.

Parameters

- **`ao_pair`** (`tuple`) – The attribute-object pair to use as a key for the ascription `dict` member.
- **`new_valueset`** (`ValueSet`) – The new ValueSet object to assign to the corresponding attribute-object pair given by the `ao_pair` paramater in the ascription member

Raises

- **`TypeError`** – `ao_pair` parameter must be a `tuple` and `new_valueset` parameter must be a `list`, `set`, or ValueSet object.
- **`ValueError`** – `ao_pair` parameter must be a 2-tuple (`str`,`str`) and `new_valueset` parameter must be a non-empty subset of the ValueSet object of the Attribute object corresponding to the attribute in the `ao_pair` parameter.
- **`KeyError`** – `ao_pair` must be a key in `ascriptions` member of this State object.

valueset module.

Supports any object provided they implement `__deepcopy__`, `__eq__`, `__str__`, `__hash__`, and provide a parser for truth value evaluation. Additionally, `__le__` in ValueSet class must be extended to support the object if the object uses a non-standard form of equality, (e.g. Point objects are subset of generic Point of same dimension).

class `valueset.`**`ValueSet`**(*valueset*)

ValueSet class.

The ValueSet class uses the `total_ordering` decorator so strict subsets, supersets and strict supersets are also available via the <, >=, and > operators respectively, despite the lack of magic functions for them.

Variables

- **`_base_types`** – The literal types supported by the ValueSet class.
- **`_object_types`** – The object types supported by the ValueSet class.
- **`values`** – The values contained in the ValueSet object.
- **`_is_ValueSet`** – An identifier to use in place of type or isinstance.

`__add__`(*other*)

Overloaded + operator for ValueSet. Take the union of two ValueSets or add a single element to this Valueset. If adding an object, the object must be within `_object_types`.

`__contains__`(*key*)

Overloaded `in` operator for ValueSet. Determine if a value is contained in this ValueSet object.

Parameters **`key`** – the item to test for membership in this ValueSet.

`__deepcopy__`(*memo*)

Deepcopy a ValueSet object via the `copy.deepcopy` method.

`__eq__`(*other*)

Determine if two ValueSet objects are equal via the == operator.

`__getitem__`(*key*)

Retrive the value located at the index given by `key` parameter via indexing (e.g. `ValueSet[key]`).

Parameters **`key`** (*`int`*) – The index to use for retrieval.

Raises

- **`IndexError`** – `key` index must be in {0,. . ., *n*-1} where *n* is the number of values contained in the ValueSet object.

- **TypeError** – `key` must be an int.

__iadd__(*other*)
Overloaded += for ValueSet. Take the union of two ValueSets or add a single element to this Valueset. If adding an object, the object must be within `_object_types`.

__init__(*valueset*)
Construct a ValueSet object.

Parameters **valueset** (*list | set*) – The values to place in the ValueSet object. These values are passed through the `_parse` function before being stored.

Raises **TypeError** – `valueset` parameter must be a python `list` or `set`.

__iter__()
Provides an iterator for ValueSet (e.g. "`for value in ValueSet:`").

__le__(*other*)
Overloaded <= operator for ValueSet object. Determine if this ValueSet object is a subset of the ValueSet object contained in `other` parameter.

__len__()
Determine the length of a ValueSet object via the `len` built-in function e.g.(`len(ValueSet)`).

__ne__(*other*)
Determine if two ValueSet objects are not equal via the `!=` operator.

__nonzero__()
Determine if a ValueSet is falsy (e.g. `if ValueSet` or `if not ValueSet`).

__repr__()
Return a string representation of a ValueSet object with the following form: "V(v_1, . . . ,v_n)".

__setitem__(*key*, *value*)
Assign a value in `value` parameter to a ValueSet object at the index given by `key` parameter (e.g. `ValueSet[key] = value`).

Parameters

- **key** (*int*) – The index to use for assignment.
- **value** – The value to assign at index given by `key`.

Raises

- **AttributeError** – An invalid/unsupported object is given as `value` parameter.
- **IndexError** – `key` index must be in {0,. . ., *n*-1} where *n* is the number of values contained in the ValueSet object.
- **TypeError** – `key` must be an int.
- **ValueError** – Duplicate values are not allowed in a ValueSet.

__str__()
Return a readable string representation of a ValueSet object with the following form: "V(v_1, . . . ,v_n)".

__sub__(*other*)
Overloaded − operator for ValueSet. This functions as the set-theoretic difference.

static _parse(*values*)
Parse a list into the standard format used by ValueSet objects. Any ints, longs, and floats are absorbed into an Interval object if they are contained by that Interval and the base types contained in `values` are sorted.

Returns filtered, sorted values in a standard format.

Return type `list`

Raises **`TypeError`** – `values` parameter must be either a python `list` or `set`.

static `_split_by_types`(*values*)

Split an iterable object by the types of elements within it and return a defaultdict where keys are the types composing the iterable object and the values are lists of the values of the iterable object falling into those types.

Parameters **`values`** (*`list` | `set` | `ValueSet` | `...`*) – An iterable object to split.

Returns defaultdict of lists where keys correspond to `ValueSet._base_type` and `ValueSet._object_types` present in `values` parameter.

Return type `defaultdict(list)`

Raises

- **`AttributeError`** – Only objects contianing a single identifier in `_object_types` are supported.
- **`TypeError`** – An invalid type exists in the iterable object.

classmethod `add_object_type`(*object_identifier*)

Add compatibility for an object to the ValueSet class. This is part of the vivid object extension protocol.

Parameters **`object_identifier`** (*`str`*) – The identifier used by each instance of a class. This must be of the form: "_is_Object" (e.g. `_is_Point` or `_is_Interval`).

variable_assignment module.

class `variable_assignment.`**`VariableAssignment`**(*vocabulary*, *attribute_system*, *mapping*, *dummy=False*)

VariableAssignment class. A VariableAssignment is a total function χ from the variables V of some Vocabulary to the objects $\{s_1, \ldots, s_n\}$ of some AttributeSystem.

Variables

- ***`vocabulary`*** – a reference to the Vocabulary object the VariableAssignment is defined over.
- ***`attribute_system`*** – a copy of the AttributeSystem the VariableAssignment originates from.
- **`mapping`** – The mapping $V \longrightarrow \{s_1, \ldots, s_n\}$
- **`source`** – The variable used in the total mapping χ.
- **`target`** – The objects used in the total mapping χ.
- **`_is_VariableAssignment`** – An identifier to use in place of type or isinstance.

`__deepcopy__`(*memo*)

Deepcopy a ConstantAssignment object via the `copy.deepcopy` method. This does not break the reference to `vocabulary` member.

`__eq__`(*other*)

Determine if two VariableAssignment objects are equal via the == operator.

`__getitem__`(*key*)

Retrive the object mapped to the constant given by `key` parameter via indexing (e.g. `VariableAssignment[key]`).

Parameters **`key`** (*`str`*) – The variable to use for retrieval.

Raises

- **KeyError** – variable given by `key` parameter is not in this VariableAssignment's `source`.
- **TypeError** – `key` parameter must be a `str`.

__init__(*vocabulary*, *attribute_system*, *mapping*, *dummy=False*)
Construct a VariableAssignment object.

Parameters

- **vocabulary** (`Vocabulary`) – The Vocabulary the VariableAssignment is defined over.
- **attribute_system** (`AttributeSystem`) – The AttributeSystem from which the objects in the Assignment come from.
- **mapping** (`dict`) – The mapping χ from the variables V of `vocabulary` to the objects $\{s_1, \ldots, s_n\}$ of `attribute_system`.
- **dummy** (`bool`) – A flag for creating a dummy (i.e., empty) VariableAssignment object.

Raises

- **TypeError** – `vocabulary` parameter must be a Vocabulary object, `attribute_system` parameter must be an AttributeSystem object and `mapping` parameter must be a `dict` with `str` keys and values.
- **ValueError** – all keys in `mapping` parameter must be in `vocabulary` parameter's variables and all values in `mapping` parameter must be unique and match some object in `attribute_system` parameter and variables must span all of V (unless dummy flag is on).

__ne__(*other*)
Determine if two VariableAssignment objects are not equal via the `!=` operator.

__repr__()
Return a string representation of a VariableAssignment object.

__str__()
Return a readable string representation of a VariableAssignment object.

vocabulary module.

class `vocabulary.`**Vocabulary**(*C*, *R*, *V*)
First-Order Vocabulary class.

Variables

- **C** – The constants of the vocabulary.
- **R** – The relation symbols of the vocabulary.
- **V** – the variables of the vocabulary.

__contains__(*key*)
Determine if a Vocabulary contains the `str` or RelationSymbol object in `key` parameter.

Parameters **key** (*RelationSymbol | str*) – The `str` or RelationSymbol object to test for membership in this Vocabulary.

__deepcopy__(*memo*)
Deepcopy a Vocabulary object via the `copy.deepcopy` method.

__eq__(*other*)
Determine if two Vocabulary objects are equal via == operator.

`__hash__``()`
Hash implementation for set functionality of Vocabulary objects.

`__init__``(`*C*, *R*, *V*`)`
Construct a Vocabulary object. Each parameter `C`, `R` and `V` are sorted before being stored.

Parameters

- **C** (`list`) – The constants of the Vocabulary object; held as a `list` of `str`s.
- **R** (`list`) – The relation symbols of the Vocabulary object; held as a `list` of Relation-Symbol objects.
- **V** (`list`) – The variables of the Vocabulary object; held as a `list` of `str`s.

Raises

- **`TypeError`** – `C`, `R`, and `V` parameters must all be lists, `C` and `V` must be contain only `str`s and `R` must contain only RelationSymbol objects.
- **`ValueError`** – `C` and `V` cannot overlap and duplicates are not permitted in any of the lists.

`__ne__``(`*other*`)`
Determine if two Vocabulary objects are not equal via != operator.

`__repr__``()`
Return a string representation of a Vocabulary object.

`__str__``()`
Return a readable string representation of a Vocabulary object.

`_key``()`
Private key function for hashing.

Returns 3-tuple consisting of (`C`, `R`, `V`)

Return type tuple

`add_constant``(`*constant*`)`
Add a constant to this Vocabulary object's `C`.

Parameters **`constant`** (*`str`*) – the new constant to add to the Vocabulary's `C`.

Raises

- **`TypeError`** – `constant parameter must be a ``str`.
- **`ValueError`** – duplicate symbols are not permitted.

`add_variable``(`*variable*`)`
Add a constant to this Vocabulary object's `V`.

Parameters **`variable`** (*`str`*) – the new variable to add to the Vocabulary's `V`.

Raises

- **`TypeError`** – `variable parameter must be a ``str`.
- **`ValueError`** – duplicate symbols are not permitted.

parser_set module.

class `parser_set.`**`ParserSet`**
ParserSet class. ParserSet objects function as a sequence/collection. The ParserSet class is part of the vivid object extension protocol.

Variables

- **`parsers`** – The parsers contained in the ParserSet object.
- **`_is_ParserSet`** – An identifier to use in place of type or isinstance.

`__getitem__`(*key*)
Retrive the parser located at the index given by `key` parameter via indexing (e.g. `ParserSet[key]`).

Parameters **`key`** (`int`) – The index to use for retrieval.

Raises **`TypeError`** – `key` parameter must be an index.

`__init__`()
Construct a ParserSet object.

`__iter__`()
Provides an iterator for ParserSet (e.g. "`for parser in ParserSet:`").

`__len__`()
Determine the length of the ParserSet object via the `len` built-in function e.g.(`len(ParserSet)`).

point_parser module.

class `point_parser.`**`PointParser`**
PointParser class. The PointParser class is used for parsing Point object related expressions.

Variables **`_is_Parser`** – An identifier to use in place of type or isinstance.

`__call__`(**args*)
Call PointParser object (e.g., `PointParser(expression)`).

`__init__`()
Construct a PointParser object.

`_eval`(*string*)
Try to evaluate given string (e.g., "`is_on(P(2.0,2.0),P(1.0,1.0),P(3.0,3.0))`").

Parameters **`string`** (`str`) – The expression to evaluate; the PointParser object unstringifies Point objects in `string` parameter and tries to call a function of the Point object (also given by `string` parameter) with unstringified Points as arguments.

Raises **`ValueError`** – Function provided in `string` parameter is not a function in the Point class, some argument is not a Point after trying to unstringify or the `string` parameter is improperly formatted.

truth_value_parser module.

class `truth_value_parser.`**`TruthValueParser`**
TruthValueParser class. TruthValueParser provides parsing functionality for entirely mathematical/logical strings.

Variables **`_is_Parser`** – An identifier to use in place of type or isinstance.

`__call__`(**args*)
Call TruthValueParser object (e.g., `TruthValueParser(expression)`).

`__init__`()
Construct a TruthValueParser object.

`_eval`(*string*)
Try to evaluate given string in `string` parameter. (e.g.,"`(4 < 5 * cos(2 * PI) and 4*e^3 > 3 *(3 + 3))and!(2 < 3)`").

Parameters **`string`** (`str`) – The expression to evaluate.

CHAPTER ONE

INDICES AND TABLES

- genindex
- modindex
- search

PYTHON MODULE INDEX

Symbols