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dimod is a shared API for binary quadratic samplers. It provides a binary quadratic model (BQM) class that contains Ising and quadratic unconstrained binary optimization (QUBO) models used by samplers such as the D-Wave system. It also provides utilities for constructing new samplers and composed samplers and for minor-embedding. Its reference examples include several samplers and composed samplers.
The QUBO form, \( E(a_i, b_{i,j}; q_i) = -q_1 - q_2 + 2q_1q_2 \), is related to the Ising form, \( E(h_i, j_{i,j}; s_i) = \frac{1}{2}(s_1s_2 - 1) \), via the simple manipulation \( s_i = 2q_i - 1 \).

This example constructs a simple QUBO and converts it to Ising format.

```python
>>> import dimod
>>> bqm = dimod.BinaryQuadraticModel({0: -1, 1: -1}, {(0, 1): 2}, 0.0, dimod.BINARY)
# QUBO
>>> bqm_ising = bqm.change_vartype(dimod.SPIN, inplace=False)  # Ising
```

This example uses one of dimod’s test samplers, ExactSolver, a solver that calculates the energies of all possible samples.

```python
>>> import dimod
>>> h = {0: 0.0, 1: 0.0}
>>> J = {(0, 1): -1.0}
>>> bqm = dimod.BinaryQuadraticModel.from_ising(h, J)
>>> response = dimod.ExactSolver().sample(bqm)
>>> for sample, energy in response.data(["sample", 'energy']): print(sample, energy)
{0: -1, 1: -1} -1.0
{0: 1, 1: 1} 1.0
{0: 1, 1: -1} 1.0
{0: -1, 1: 1} 1.0
```
花瓣绽放的瞬间，花朵宛如被定格在时间的那一刻，优雅而静谧。周围的色彩似乎也因这花而变得更加柔和，仿佛大自然正以它特有的方式为这幕盛景做着铺垫。花瓣的边缘细腻而精致，每一瓣都如同精心雕琢的艺术品，展现出自然界的鬼斧神工。花瓣的纹理清晰可见，微风拂过，花瓣轻轻摇曳，仿佛在诉说着自己的故事。花瓣的色彩在阳光的照射下显得格外鲜艳，红、粉、白等颜色交织在一起，形成一幅美丽的画卷。花瓣的轻盈与果实的厚重形成了鲜明的对比，果实的重量似乎在支撑着花瓣的轻柔，共同构成了一幅动人的画面。花瓣的美丽不仅仅在于其外表，更在于它所蕴含的生命力和希望。在花瓣的绽放中，我们看到了生命的奇迹，感受到了大自然的神秘与力量。花瓣的绽放，是大自然对生命的礼赞，是对美好事物的向往和追求。花瓣的绽放，也是对我们的一种启示，让我们在忙碌的生活中，也能找到属于自己的那份宁静与美好。
```python
>>> import dimod

>>> linear = {1: 1, 2: 2, 3: 3, 4: 4}

>>> quadratic = {(1, 2): 12, (1, 3): 13, (1, 4): 14,
...                (2, 3): 23, (2, 4): 24,
...                (3, 4): 34}

>>> bqm_k4 = dimod.BinaryQuadraticModel(linear, quadratic, 0.5, dimod.SPIN)

>>> bqm_k4.vartype
<Vartype.SPIN: frozenset([1, -1])>

>>> len(bqm_k4.linear)
4

>>> bqm_k4.contract_variables(2, 3)

>>> len(bqm_k4.linear)
3

>>> bqm_no3_qubo = bqm_k4.binary

>>> bqm_no3_qubo.vartype
<Vartype.BINARY: frozenset([0, 1])>
```

### 2.1.2 Samplers and Composites

_Samplers_ are processes that sample from low-energy states of a problem’s objective function. A binary quadratic model (BQM) sampler samples from low-energy states in _models_ such as those defined by an Ising equation or a QUBO problem and returns an iterable of samples, in order of increasing energy. A dimod sampler provides ‘sample_qubo’ and ‘sample_ising’ methods as well as the generic BQM sampler method.

_Composed samplers_ apply pre- and/or post-processing to binary quadratic programs without changing the underlying sampler implementation by layering composite patterns on the sampler. For example, a composed sampler might add spin transformations when sampling from the D-Wave system.

_Structured samplers_ are restricted to sampling only binary quadratic models defined on a specific graph.

You can create your own samplers with dimod’s _Sampler_ abstract base class (ABC) providing complementary methods (e.g., ‘sample_qubo’ if only ‘sample_ising’ is implemented), consistent responses, etc.

### Examples

This first example uses a composed sampler on the Boolean NOT Gate example detailed in the Getting Started documentation. The _ExactSolver_ test sampler calculates the energy of all possible samples; the _FixedVariableComposite_ composite sets the value and removes specified variables from the BQM before sending it to the sampler. Fixing variable `x`, the input to the NOT gate, to 1 results in valid solution `z = 0` having lower energy (-1) than solution `x = z = 1`, which is an invalid state for a NOT gate.

```python
>>> from dimod import FixedVariableComposite, ExactSolver

>>> Q = {('x', 'x'): -1, ('x', 'z'): 2, ('z', 'x'): 0, ('z', 'z'): -1}

>>> composed_sampler = FixedVariableComposite(ExactSolver())

>>> sampleset = composed_sampler.sample_qubo(Q, fixed_variables={'x': 1})

>>> print(sampleset)
  x  z  energy  num_oc.
0 1  0   -1.0     1
1 1  1    0.0     1

['BINARY', 2 rows, 2 samples, 2 variables]
```

The next example creates a dimod sampler by implementing a single method (in this example the _sample_ising_ method).
class LinearIsingSampler(dimod.Sampler):
    def sample_ising(self, h, J):
        sample = linear_ising(h, J)  # Defined elsewhere
        energy = dimod.ising_energy(sample, h, J)
        return dimod.Response.from_samples([sample], {'energy': [energy]})

@property
    def properties(self):
        return dict()

@property
    def parameters(self):
        return dict()

The Sampler ABC provides the other sample methods “for free” as mixins.

2.1.3 Terminology

chain A collection of nodes or variables in the target graph/model that we want to act as a single node/variable.
chain strength Magnitude of the negative quadratic bias applied between variables to form a chain.
composed sampler Samplers that apply pre- and/or post-processing to binary quadratic programs without changing the underlying sampler implementation by layering composite patterns on the sampler. For example, a composed sampler might add spin transformations when sampling from the D-Wave system.
graph A collection of nodes and edges. A graph can be derived from a model: a node for each variable and an edge for each pair of variables with a non-zero quadratic bias.
model A collection of variables with associated linear and quadratic biases. Sometimes referred to in other tools as a problem.
sampler A process that samples from low energy states of a problem’s objective function. A binary quadratic model (BQM) sampler samples from low energy states in models such as those defined by an Ising equation or a Quadratic Unconstrained Binary Optimization (QUBO) problem and returns an iterable of samples, in order of increasing energy. A dimod sampler provides ‘sample_qubo’ and ‘sample_ising’ methods as well as the generic BQM sampler method.
source In the context of embedding, the model or induced graph that we wish to embed. Sometimes referred to in other tools as the logical graph/model.
structured sampler Samplers that are restricted to sampling only binary quadratic models defined on a specific graph.
target Embedding attempts to create a target model from a target graph. The process of embedding takes a source model, derives the source graph, maps the source graph to the target graph, then derives the target model. Sometimes referred to in other tools as the embedded graph/model.

2.2 Reference Documentation

Release 0.8.21
Date Feb 20, 2020
2.2.1 Binary Quadratic Models

Ising, QUBO, and BQMs

The binary quadratic model (BQM) class contains Ising and quadratic unconstrained binary optimization (QUBO) models used by samplers such as the D-Wave system. The Ising model is an objective function of \( N \) variables \( s = [s_1, ..., s_N] \) corresponding to physical Ising spins, where \( h_i \) are the biases and \( J_{i,j} \) the couplings (interactions) between spins.

\[
\text{Ising: } E(s| h, J) = \left\{ \sum_{i=1}^{N} h_i s_i + \sum_{i<j}^{N} J_{i,j} s_i s_j \right\} \quad s_i \in \{-1, +1\}
\]

The QUBO model is an objective function of \( N \) binary variables represented as an upper-diagonal matrix \( Q \), where diagonal terms are the linear coefficients and the nonzero off-diagonal terms the quadratic coefficients.

\[
\text{QUBO: } E(x|Q) = \sum_{i\leq j}^{N} x_i Q_{i,j} x_j \quad x_i \in \{0, 1\}
\]

The \( \text{BinaryQuadraticModel} \) class can contain both these models and its methods provide convenient utilities for working with, and interworking between, the two representations of a problem.

These models and their use in solving problems on the D-Wave system is described in the following documentation:

- **Getting Started with the D-Wave System** Introduces key concepts such as objective functions, Ising model, QUBOs, and graphs, explains how these models are used to represent problems, and provides some simple examples.
- **D-Wave Problem-Solving Handbook** Provides a variety of techniques for, and examples of, reformulating problems as BQMs.
- **Solving Problems on a D-Wave System** Describes and demonstrates the use of BQM in the context of Ocean software.

Class

class BinaryQuadraticModel(linear, quadratic, offset, vartype, **kwargs)

Encodes a binary quadratic model.

Binary quadratic model is the superclass that contains the Ising model and the QUBO.

Parameters

- **linear (dict [variable, bias])** – Linear biases as a dict, where keys are the variables of the binary quadratic model and values the linear biases associated with these variables. A variable can be any python object that is valid as a dictionary key. Biases are generally numbers but this is not explicitly checked.
- **quadratic (dict [(variable, variable), bias])** – Quadratic biases as a dict, where keys are 2-tuples of variables and values the quadratic biases associated with the pair of variables (the interaction). A variable can be any python object that is valid as a dictionary key. Biases are generally numbers but this is not explicitly checked. Interactions that are not unique are added.
- **offset (number)** – Constant energy offset associated with the binary quadratic model. Any input type is allowed, but many applications assume that offset is a number. See \( \text{BinaryQuadraticModel.energy()} \).
• **vartype** *(Vartype/str/set)* – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

• **kwargs** – Any additional keyword parameters and their values are stored in `BinaryQuadraticModel.info`

**Notes**

The `BinaryQuadraticModel` class does not enforce types on biases and offsets, but most applications that use this class assume that they are numeric.

**Examples**

This example creates a binary quadratic model with three spin variables.

```python
>>> bqm = dimod.BinaryQuadraticModel({0: 1, 1: -1, 2: .5},
...     {(0, 1): .5, (1, 2): 1.5},
...     1.4,
...     dimod.Vartype.SPIN)
```

This example creates a binary quadratic model with non-numeric variables (variables can be any hashable object).

```python
>>> bqm = dimod.BQM({'a': 0.0, 'b': -1.0, 'c': 0.5},
...     {('a', 'b'): -1.0, ('b', 'c'): 1.5},
...     1.4,
...     dimod.SPIN)
```

**linear**

Linear biases as a dict, where keys are the variables of the binary quadratic model and values the linear biases associated with these variables.

  **Type**  `dict[variable, bias]`

**quadratic**

Quadratic biases as a dict, where keys are 2-tuples of variables, which represent an interaction between the two variables, and values are the quadratic biases associated with the interactions.

  **Type**  `dict[(variable, variable), bias]`

**offset**

The energy offset associated with the model. Same type as given on instantiation.

  **Type**  `number`

**vartype**

The model’s type. One of `Vartype.SPIN` or `Vartype.BINARY`.

  **Type**  `Vartype`

**variables**

The variables in the binary quadratic model as a dictionary keys view object.
Type keysview

**adj**
The model’s interactions as nested dicts. In graphic representation, where variables are nodes and interactions are edges or adjacencies, keys of the outer dict (*adj*) are all the model’s nodes (e.g. *v*) and values are the inner dicts. For the inner dict associated with outer-key/node ‘*v*’, keys are all the nodes adjacent to *v* (e.g. *u*) and values are quadratic biases associated with the pair of inner and outer keys (*u*, *v*).

Type dict

**info**
A place to store miscellaneous data about the binary quadratic model as a whole.

Type dict

**SPIN**
An alias of `Vartype.SPIN` for easier access.

Type `Vartype`

**BINARY**
An alias of `Vartype.BINARY` for easier access.

Type `Vartype`

**Examples**

This example creates an instance of the `BinaryQuadraticModel` class for the K4 complete graph, where the nodes have biases set equal to their sequential labels and interactions are the concatenations of the node pairs (e.g., 23 for *u*,*v* = 2,3).

```python
>>> import dimod
... linear = {1: 1, 2: 2, 3: 3, 4: 4}
>>> quadratic = {(1, 2): 12, (1, 3): 13, (1, 4): 14,
... (2, 3): 23, (2, 4): 24,
... (3, 4): 34}
>>> offset = 0.0
>>> vartype = dimod.BINARY
>>> bqm_k4 = dimod.BinaryQuadraticModel(linear, quadratic, offset, vartype)
>>> bqm_k4.info = {'Complete K4 binary quadratic model.'}
>>> bqm_k4.info.issubset({'Complete K3 binary quadratic model.',
... 'Complete K4 binary quadratic model.',
... 'Complete K5 binary quadratic model.'})
True
>>> bqm_k4.adj.viewitems()  # Show all adjacencies # doctest: +SKIP
[(1, {2: 12, 3: 13, 4: 14}),
 (2, {1: 12, 3: 23, 4: 24}),
 (3, {1: 13, 2: 23, 4: 34}),
 (4, {1: 14, 2: 24, 3: 34})]
>>> bqm_k4.adj[2]  # Show adjacencies for node 2  # doctest: +SKIP
{1: 12, 3: 23, 4: 24}
>>> bqm_k4.adj[2][3]  # Show the quadratic bias for nodes 2,3 # doctest: ...
23
```
Vartype Properties

QUBO (binary-valued variables) and Ising (spin-valued variables) instances of a BQM.

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>BinaryQuadraticModel.binary</code></td>
<td>An instance of the QUBO model subclass of the <code>BinaryQuadraticModel</code> superclass (a BQM with binary variables).</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.spin</code></td>
<td>An instance of the Ising model subclass of the <code>BinaryQuadraticModel</code> superclass (a BQM with spin variables).</td>
</tr>
</tbody>
</table>

**dimod.BinaryQuadraticModel.binary**

An instance of the QUBO model subclass of the `BinaryQuadraticModel` superclass (a BQM with binary variables).

Enables access to biases for the binary-valued binary quadratic model regardless of the `vartype` set when the model was created. If the model was created with the `spin` vartype, the QUBO model subclass is instantiated upon the first use of the `binary` property and used in any subsequent reads.

**Examples**

This example creates an Ising model and uses the `binary` property to instantiate the corresponding QUBO model.

```python
>>> import dimod
... >>> bqm_spin = dimod.BinaryQuadraticModel({0: 0.0, 1: 0.0}, {(0, 1): 0.5}, -0.5, dimod.SPIN)
... >>> bqm_qubo = bqm_spin.binary
... >>> bqm_qubo
... BinaryQuadraticModel({0: -1.0, 1: -1.0}, {(0, 1): 2.0}, 0.0, Vartype.BINARY)
... >>> bqm_qubo.binary is bqm_qubo
... True
```

**Note:** Methods like `add_variable()`, `add_variables_from()`, `add_interaction()`, etc. should only be used on the base model.

**Type** `BinaryQuadraticModel`

**dimod.BinaryQuadraticModel.spin**

An instance of the Ising model subclass of the `BinaryQuadraticModel` superclass (a BQM with spin variables).

Enables access to biases for the spin-valued binary quadratic model regardless of the `vartype` set when the model was created. If the model was created with the `binary` vartype, the Ising model subclass is instantiated upon the first use of the `spin` property and used in any subsequent reads.

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Examples

This example creates a QUBO model and uses the `spin` property to instantiate the corresponding Ising model.

```python
>>> import dimod
... >>> bqm_qubo = dimod.BinaryQuadraticModel({0: -1, 1: -1}, {(0, 1): 2}, 0.0, dimod.BINARY)
... >>> bqm_spin = bqm_qubo.spin
... >>> bqm_spin # doctest: +SKIP
BinaryQuadraticModel({0: 0.0, 1: 0.0}, {(0, 1): 0.5}, -0.5, Vartype.SPIN)
... >>> bqm_spin.spin is bqm_spin
True
```

**Note:** Methods like `add_variable()`, `add_variables_from()`, `add_interaction()`, etc. should only be used on the base model.

Type `BinaryQuadraticModel`

Methods

Construction Shortcuts

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>BinaryQuadraticModel.empty(vartype)</code></td>
<td>Create an empty binary quadratic model.</td>
</tr>
</tbody>
</table>

`dimod.BinaryQuadraticModel.empty`

**classmethod** `BinaryQuadraticModel.empty(vartype)`

Create an empty binary quadratic model.

Equivalent to instantiating a `BinaryQuadraticModel` with no bias values and zero offset for the defined `vartype`:

```
BinaryQuadraticModel({}, {}, 0.0, vartype)
```

**Parameters** `vartype` *(Vartype/str/set)*  – Variable type for the binary quadratic model. Accepted input values:

- `Vartype.SPIN`, 'SPIN', {-1, 1}
- `Vartype.BINARY`, 'BINARY', {0, 1}

**Examples**

```python
>>> bqm = dimod.BinaryQuadraticModel.empty(dimod.BINARY)
```

Adding and Removing Variables and Interactions
<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>BinaryQuadraticModel.add_variable(v, bias[, ...])</code></td>
<td>Add variable v and/or its bias to a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.add_variables_from(linear)</code></td>
<td>Add variables and/or linear biases to a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.add_interaction(u, v, bias)</code></td>
<td>Add an interaction and/or quadratic bias to a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.add_interactions_from(...)</code></td>
<td>Add interactions and/or quadratic biases to a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.add_offset(offset)</code></td>
<td>Add specified value to the offset of a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.remove_variable(v)</code></td>
<td>Remove variable v and all its interactions from a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.remove_variables_from(...)</code></td>
<td>Remove specified variables and all of their interactions from a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.remove_interaction(u, v)</code></td>
<td>Remove interaction of variables u, v from a binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.remove_interactions_from(...)</code></td>
<td>Remove all specified interactions from the binary quadratic model.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.remove_offset()</code></td>
<td>Set the binary quadratic model’s offset to zero.</td>
</tr>
<tr>
<td><code>BinaryQuadraticModel.update(bqm[, ignore_info])</code></td>
<td>Update one binary quadratic model from another.</td>
</tr>
</tbody>
</table>

**dimod.BinaryQuadraticModel.add_variable**

`BinaryQuadraticModel.add_variable(v, bias, vartype=None)`

Add variable v and/or its bias to a binary quadratic model.

**Parameters**

- **v (variable)** – The variable to add to the model. Can be any python object that is a valid dict key.
- **bias (bias)** – Linear bias associated with v. If v is already in the model, this value is added to its current linear bias. Many methods and functions expect bias to be a number but this is not explicitly checked.
- **vartype (Vartype, optional, default=None)** – Vartype of the given bias. If None, the vartype of the binary quadratic model is used. Valid values are Vartype.SPIN or Vartype.BINARY.

**Examples**

This example creates an Ising model with two variables, adds a third, and adds to the linear biases of the initial two.

```python
>>> import dimod
... >>> bqm = dimod.BinaryQuadraticModel({0: 0.0, 1: 1.0}, {(0, 1): 0.5}, -0.5, dimod.SPIN)
>>> len(bqm.linear)
2
>>> bqm.add_variable(2, 2.0, vartype=dimod.SPIN)    # Add a new variable
>>> bqm.add_variable(1, 0.33, vartype=dimod.SPIN)    # Binary value is converted to spin value
>>> bqm.add_variable(0, 0.33, vartype=dimod.BINARY)  # Binary value is...
```

(continues on next page)
dimod.BinaryQuadraticModel.add_variables_from

BinaryQuadraticModel.add_variables_from(linear, vartype=None)

Add variables and/or linear biases to a binary quadratic model.

Parameters

- **linear** (dict[variable, bias]/iterable[(variable, bias)]) – A collection of variables and their linear biases to add to the model. If a dict, keys are variables in the binary quadratic model and values are biases. Alternatively, an iterable of (variable, bias) pairs. Variables can be any python object that is a valid dict key. Many methods and functions expect the biases to be numbers but this is not explicitly checked. If any variable already exists in the model, its bias is added to the variable’s current linear bias.

- **vartype** (Vartype, optional, default=None) – Vartype of the given bias. If None, the vartype of the binary quadratic model is used. Valid values are Vartype.SPIN or Vartype.BINARY.

Examples

This example creates creates an empty Ising model, adds two variables, and subsequently adds to the bias of the one while adding a new, third, variable.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({}, {}, 0.0, dimod.SPIN)
>>> len(bqm.linear)
0
>>> bqm.add_variables_from({'a': .5, 'b': -1.})
>>> 'b' in bqm
True
>>> bqm.add_variables_from({'b': -1., 'c': 2.0})
>>> bqm.linear['b']
-2.0
```

dimod.BinaryQuadraticModel.add_interaction

BinaryQuadraticModel.add_interaction(u, v, bias, vartype=None)

Add an interaction and/or quadratic bias to a binary quadratic model.

Parameters

- **u** (variable) – One of the pair of variables to add to the model. Can be any python object that is a valid dict key.

- **v** (variable) – One of the pair of variables to add to the model. Can be any python object that is a valid dict key.

---
• **bias** (*bias*) – Quadratic bias associated with u, v. If u, v is already in the model, this value is added to the current quadratic bias. Many methods and functions expect *bias* to be a number but this is not explicitly checked.

• **vartype** (*Vartype*, optional, default=None) – Vartype of the given bias. If None, the vartype of the binary quadratic model is used. Valid values are *Vartype.SPIN* or *Vartype.BINARY*.

**Examples**

This example creates an Ising model with two variables, adds a third, adds to the bias of the initial interaction, and creates a new interaction.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({0: 0.0, 1: 1.0}, {(0, 1): 0.5}, -0.5, dimod.SPIN)
>>> len(bqm.quadratic)
1
>>> bqm.add_interaction(0, 2, 2)                     # Add new variable 2
>>> bqm.add_interaction(0, 1, .25)
>>> bqm.add_interaction(1, 2, .25, vartype=dimod.BINARY)  # Binary value is converted to spin value
>>> len(bqm.quadratic)
3
>>> bqm.quadratic[(0, 1)]
0.75
```

dimod.BinaryQuadraticModel.add_interactions_from

*BinaryQuadraticModel.add_interactions_from*(*quadratic*, *vartype=None*)

Add interactions and/or quadratic biases to a binary quadratic model.

**Parameters**

• **quadratic** (*dict* [(variable, variable), *bias*]/*iterable* [(variable, variable, *bias*)]) – A collection of variables that have an interaction and their quadratic bias to add to the model. If a dict, keys are 2-tuples of variables in the binary quadratic model and values are their corresponding bias. Alternatively, an iterable of 3-tuples. Each interaction in *quadratic* should be unique; that is, if *(u, v)* is a key, *(v, u)* should not be. Variables can be any python object that is a valid dict key. Many methods and functions expect the biases to be numbers but this is not explicitly checked.

• **vartype** (*Vartype*, optional, default=None) – Vartype of the given bias. If None, the vartype of the binary quadratic model is used. Valid values are *Vartype.SPIN* or *Vartype.BINARY*.

**Examples**

This example creates an empty Ising model, adds an interaction for two variables, adds to its bias while adding a new variable, then adds another interaction.
```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel.empty(dimod.SPIN)
>>> bqm.add_interactions_from({('a', 'b'): -.5})
-0.5
>>> bqm.add_interactions_from({('a', 'b'): -.5, ('a', 'c'): 2})
>>> bqm.add_interactions_from({('b', 'c'): 2}, vartype=dimod.BINARY)  # Binary
˓→value is converted to spin value
>>> len(bqm.quadratic)
3
>>> bqm.quadratic[('a', 'b')]
-1.0
```

**dimod.BinaryQuadraticModel.add_offset**

BinaryQuadraticModel.add_offset(offset)

Add specified value to the offset of a binary quadratic model.

**Parameters**

- **offset** (number) – Value to be added to the constant energy offset of the binary quadratic model.

**Examples**

This example creates an Ising model with an offset of -0.5 and then adds to it.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({0: 0.0, 1: 0.0}, {(0, 1): 0.5}, -0.5, dimod.
˓→SPIN)
>>> bqm.add_offset(1.0)
>>> bqm.offset
0.5
```

**dimod.BinaryQuadraticModel.remove_variable**

BinaryQuadraticModel.remove_variable(v)

Remove variable v and all its interactions from a binary quadratic model.

**Parameters**

- **v** (variable) – The variable to be removed from the binary quadratic model.

**Notes**

If the specified variable is not in the binary quadratic model, this function does nothing.

**Examples**

This example creates an Ising model and then removes one variable.
```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({'a': 0.0, 'b': 1.0, 'c': 2.0},
...    {('a', 'b'): 0.25, ('a', 'c'): 0.5, ('b', 'c'): 0.75},
...    -0.5, dimod.SPIN)
>>> bqm.remove_variable('a')
>>> 'a' in bqm.linear
False
>>> {'b', 'c'} in bqm.quadratic
True
```

### dimod.BinaryQuadraticModel.remove_variables_from

`BinaryQuadraticModel.remove_variables_from(variables)`

Remove specified variables and all of their interactions from a binary quadratic model.

**Parameters**

- `variables` *(iterable)* — A collection of variables to be removed from the binary quadratic model. If any variable is not in the model, it is ignored.

**Examples**

This example creates an Ising model with three variables and interactions among all of them, and then removes two variables.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({0: 0.0, 1: 1.0, 2: 2.0},
...    {(0, 1): 0.25, (0, 2): 0.5, (1, 2): 0.75},
...    -0.5, dimod.SPIN)
>>> bqm.remove_variables_from([0, 1])
>>> len(bqm.linear)
1
>>> len(bqm.quadratic)
0
```

### dimod.BinaryQuadraticModel.remove_interaction

`BinaryQuadraticModel.remove_interaction(u, v)`

Remove interaction of variables u, v from a binary quadratic model.

**Parameters**

- `u (variable)` — One of the pair of variables in the binary quadratic model that has an interaction.
- `v (variable)` — One of the pair of variables in the binary quadratic model that has an interaction.

**Notes**

Any interaction not in the binary quadratic model is ignored.
Examples

This example creates an Ising model with three variables that has interactions between two, and then removes an interaction.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({}, {('a', 'b'): -1.0, ('b', 'c'): 1.0}, 0.0, dimod.SPIN)
>>> bqm.remove_interaction('b', 'c')
>>> ('b', 'c') in bqm.quadratic
False
>>> bqm.remove_interaction('a', 'c')  # not an interaction, so ignored
>>> len(bqm.quadratic)
1
```

dimod.BinaryQuadraticModel.remove_interactions_from

`BinaryQuadraticModel.remove_interactions_from(interactions)`

Remove all specified interactions from the binary quadratic model.

**Parameters**

`interactions (iterable[[variable, variable]])` — A collection of interactions. Each interaction should be a 2-tuple of variables in the binary quadratic model.

**Notes**

Any interaction not in the binary quadratic model is ignored.

Examples

This example creates an Ising model with three variables that has interactions between two, and then removes an interaction.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({}, {('a', 'b'): -1.0, ('b', 'c'): 1.0}, 0.0, dimod.SPIN)
>>> bqm.remove_interactions_from([('b', 'c'), ('a', 'c')])  # 'a', 'c' is not an interaction, so ignored
>>> len(bqm.quadratic)
1
```

dimod.BinaryQuadraticModel.remove_offset

`BinaryQuadraticModel.remove_offset()`

Set the binary quadratic model’s offset to zero.

Examples

This example creates an Ising model with a positive energy offset, and then removes it.
dimod.BinaryQuadraticModel.update

BinaryQuadraticModel.update(bqm, ignore_info=True)
Update one binary quadratic model from another.

Parameters

- **bqm** (*BinaryQuadraticModel*) – The updating binary quadratic model. Any variables in the updating model are added to the updated model. Values of biases and the offset in the updating model are added to the corresponding values in the updated model.

- **ignore_info** (*bool*, optional, default=True) – If True, info in the given binary quadratic model is ignored, otherwise BinaryQuadraticModel.info is updated with the given binary quadratic model’s info, potentially overwriting values.

Examples

This example creates two binary quadratic models and updates the first from the second.

```python
>>> import dimod
...
>>> linear1 = {1: 1, 2: 2}
>>> quadratic1 = {(1, 2): 12}
>>> bqm1 = dimod.BinaryQuadraticModel(linear1, quadratic1, 0.5, dimod.SPIN)
>>> bqm1.info = {'BQM number 1'}
>>> linear2 = {2: 0.25, 3: 0.35}
>>> quadratic2 = {(2, 3): 23}
>>> bqm2 = dimod.BinaryQuadraticModel(linear2, quadratic2, 0.75, dimod.SPIN)
>>> bqm2.info = {'BQM number 2'}
>>> bqm1.update(bqm2)
>>> bqm1.offset
1.25
>>> 'BQM number 2' in bqm1.info
False
>>> bqm1.update(bqm2, ignore_info=False)
>>> 'BQM number 2' in bqm1.info
True
>>> bqm1.offset
2.0
```

Transformations

- **BinaryQuadraticModel.contract_variables**(*u, v*)
   Enforce u, v being the same variable in a binary quadratic model.
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<td>Multiply by the specified scalar all the biases and offset of a binary quadratic model.</td>
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**dimod.BinaryQuadraticModel.contract_variables**

`BinaryQuadraticModel.contract_variables(u, v)`

Enforce u, v being the same variable in a binary quadratic model.

The resulting variable is labeled ‘u’. Values of interactions between v and variables that u interacts with are added to the corresponding interactions of u.

**Parameters**

- `u (variable)` – Variable in the binary quadratic model.
- `v (variable)` – Variable in the binary quadratic model.

**Examples**

This example creates a binary quadratic model representing the K4 complete graph and contracts node (variable) 3 into node 2. The interactions between 3 and its neighbors 1 and 4 are added to the corresponding interactions between 2 and those same neighbors.

```python
>>> import dimod

>>> linear = {1: 1, 2: 2, 3: 3, 4: 4}
>>> quadratic = {(1, 2): 12, (1, 3): 13, (1, 4): 14, ...
...   (2, 3): 23, (2, 4): 24,
...   (3, 4): 34}
>>> bqm = dimod.BinaryQuadraticModel(linear, quadratic, 0.5, dimod.SPIN)
>>> bqm.contract_variables(2, 3)
>>> 3 in bqm.linear
False
>>> bqm.quadratic[(1, 2)]
25
```

**dimod.BinaryQuadraticModel.fix_variable**

`BinaryQuadraticModel.fix_variable(v, value)`

Fix the value of a variable and remove it from a binary quadratic model.

**Parameters**

- `v (variable)` – Variable in the binary quadratic model to be fixed.
• **value** (*int*) – Value assigned to the variable. Values must match the *Vartype* of the binary quadratic model.

**Examples**

This example creates a binary quadratic model with one variable and fixes its value.

```python
>>> import dimod
... >>> bqm = dimod.BinaryQuadraticModel({'a': -.5, 'b': 0.}, {('a', 'b'): -1}, 0.0, dimod.SPIN)
>>> bqm.fix_variable('a', -1)
>>> bqm.offset
0.5
>>> bqm.linear['b']
1.0
>>> 'a' in bqm
False
```

**dimod.BinaryQuadraticModel.fix_variables**

*BinaryQuadraticModel.fix_variables*(fixed)

Fix the value of the variables and remove it from a binary quadratic model.

**Parameters**

- **fixed** (*dict*) – A dictionary of variable assignments.

**Examples**

```python
>>> bqm = dimod.BinaryQuadraticModel({'a': -.5, 'b': 0., 'c': 5}, {('a', 'b'): -1}, 0.0, dimod.SPIN)
>>> bqm.fix_variables({'a': -1, 'b': +1})
```

**dimod.BinaryQuadraticModel.flip_variable**

*BinaryQuadraticModel.flip_variable*(v)

Flip variable v in a binary quadratic model.

**Parameters**

- **v** (*variable*) – Variable in the binary quadratic model. If v is not in the binary quadratic model, it is ignored.

**Examples**

This example creates a binary quadratic model with two variables and inverts the value of one.

```python
>>> import dimod
... >>> bqm = dimod.BinaryQuadraticModel({1: 1, 2: 2}, {(1, 2): 0.5}, 0.5, dimod.SPIN)
>>> bqm.flip_variable(1)
>>> bqm.linear[1], bqm.linear[2], bqm.quadratic[(1, 2)]
(-1.0, 2, -0.5)
```
dimod Documentation, Release 0.8.21

dimod.BinaryQuadraticModel.normalize

```
BinaryQuadraticModel.normalize(bias_range=1, quadratic_range=None, ignored_variables=None, ignored_interactions=None, ignore_offset=False)
```

Normalizes the biases of the binary quadratic model such that they fall in the provided range(s), and adjusts the offset appropriately.

If `quadratic_range` is provided, then `bias_range` will be treated as the range for the linear biases and `quadratic_range` will be used for the range of the quadratic biases.

Parameters

- **bias_range** *(number/pair)* – Value/range by which to normalize the all the biases, or if `quadratic_range` is provided, just the linear biases.
- **quadratic_range** *(number/pair)* – Value/range by which to normalize the quadratic biases.
- **ignored_variables** *(iterable, optional)* – Biases associated with these variables are not scaled.
- **ignored_interactions** *(iterable[tuple], optional)* – As an iterable of 2-tuples. Biases associated with these interactions are not scaled.
- **ignore_offset** *(bool, default=False)* – If True, the offset is not scaled.

Examples

```python
>>> bqm = dimod.BinaryQuadraticModel({'a': -2.0, 'b': 1.5},
...       {('a', 'b'): -1.0},
...       1.0, dimod.SPIN)
>>> max(abs(bias) for bias in bqm.linear.values())
2.0
>>> max(abs(bias) for bias in bqm.quadratic.values())
1.0
>>> bqm.normalize([-1.0, 1.0])
>>> max(abs(bias) for bias in bqm.linear.values())
1.0
>>> max(abs(bias) for bias in bqm.quadratic.values())
0.5
```

dimod.BinaryQuadraticModel.relabel_variables

```
BinaryQuadraticModel.relabel_variables(mapping, inplace=True)
```

Relabel variables of a binary quadratic model as specified by mapping.

Parameters

- **mapping** *(dict)* – Dict mapping current variable labels to new ones. If an incomplete mapping is provided, unmapped variables retain their current labels.
- **inplace** *(bool, optional, default=True)* – If True, the binary quadratic model is updated in-place; otherwise, a new binary quadratic model is returned.

Returns A binary quadratic model with the variables relabeled. If `inplace` is set to True, returns itself.
Return type *BinaryQuadraticModel*

**Examples**

This example creates a binary quadratic model with two variables and relabels one.

```python
>>> import dimod
...
>>> model = dimod.BinaryQuadraticModel({0: 0., 1: 1.}, {(0, 1): -1}, 0.0,
˓→vartype=dimod.SPIN)
>>> model.relabel_variables({0: 'a'})  # doctest: +SKIP
BinaryQuadraticModel({1: 1.0, 'a': 0.0}, {('a', 1): -1}, 0.0, Vartype.SPIN)
```

This example creates a binary quadratic model with two variables and returns a new model with relabeled variables.

```python
>>> import dimod
...
>>> model = dimod.BinaryQuadraticModel({0: 0., 1: 1.}, {(0, 1): -1}, 0.0,
˓→vartype=dimod.SPIN)
>>> new_model = model.relabel_variables({0: 'a', 1: 'b'}, inplace=False)  # doctest: +SKIP
>>> new_model.quadratic  # doctest: +SKIP
{('a', 'b'): -1}
```

dimod.BinaryQuadraticModel.scale

*BinaryQuadraticModel.scale*(scalar, ignored_variables=None, ignored_interactions=None, ignore_offset=False)

Multiply by the specified scalar all the biases and offset of a binary quadratic model.

**Parameters**

- **scalar** *(number)* – Value by which to scale the energy range of the binary quadratic model.
- **ignored_variables** *(iterable, optional)* – Biases associated with these variables are not scaled.
- **ignored_interactions** *(iterable[tuple], optional)* – As an iterable of 2-tuples. Biases associated with these interactions are not scaled.
- **ignore_offset** *(bool, default=False)* – If True, the offset is not scaled.

**Examples**

This example creates a binary quadratic model and then scales it to half the original energy range.

```python
>>> import dimod
...
>>> bqm = dimod.BinaryQuadraticModel({'a': -2.0, 'b': 2.0}, {('a', 'b'): -1.0}, 1.0,
˓→dimod.SPIN)
>>> bqm.scale(0.5)
>>> bqm.linear['a']
-1.0
```
Change Vartype

```python
>>> bqm.quadratic[('a', 'b')]
-0.5
>>> bqm.offset
0.5
```

**BinaryQuadraticModel.**

```python
change_vartype(vartype)
```

Create a binary quadratic model with the specified vartype.

**dimod.BinaryQuadraticModel.change_vartype**

```python
BinaryQuadraticModel.\change_vartype(vartype, inplace=True)
```

Create a binary quadratic model with the specified vartype.

**Parameters**

- `vartype` *(Vartype/str/set, optional)* – Variable type for the changed model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}
- `inplace` *(bool, optional, default=True)* – If True, the binary quadratic model is updated in-place; otherwise, a new binary quadratic model is returned.

**Returns** *BinaryQuadraticModel*. A new binary quadratic model with vartype matching input ‘vartype’.

**Examples**

This example creates an Ising model and then creates a QUBO from it.

```python
>>> import dimod
...
>>> bqm_spin = dimod.BinaryQuadraticModel({1: 1, 2: 2}, {(1, 2): 0.5}, 0.5, dimod.SPIN)
>>> bqm_qubo = bqm_spin.change_vartype('BINARY', inplace=False)
>>> bqm_qubo.offset, bqm_qubo.vartype
(-2.0, <Vartype.BINARY: frozenset({0, 1})>)
```

**Copy**

```python
BinaryQuadraticModel.copy()
```

Create a copy of a binary quadratic model.
**dimod.BinaryQuadraticModel.copy**

`BinaryQuadraticModel.copy()`
Create a copy of a binary quadratic model.

**Returns** `BinaryQuadraticModel`

**Examples**

```python
>>> bqm = dimod.BinaryQuadraticModel({1: 1, 2: 2}, {(1, 2): 0.5}, 0.5, dimod.SPIN)
>>> bqm2 = bqm.copy()
```

**Energy**

`BinaryQuadraticModel.energy(sample)`
Determine the energy of the specified sample of a binary quadratic model.

`BinaryQuadraticModel.energies(samples_like)`
Determine the energies of the given samples.

**dimod.BinaryQuadraticModel.energy**

`BinaryQuadraticModel.energy(sample)`
Determine the energy of the specified sample of a binary quadratic model.

Energy of a sample for a binary quadratic model is defined as a sum, offset by the constant energy offset associated with the binary quadratic model, of the sample multiplied by the linear bias of the variable and all its interactions; that is,

$$E(s) = \sum_v h_v s_v + \sum_{u,v} J_{u,v} s_u s_v + c$$

where $s_v$ is the sample, $h_v$ is the linear bias, $J_{u,v}$ the quadratic bias (interactions), and $c$ the energy offset.

Code for the energy calculation might look like the following:

```python
energy = model.offset  # doctest: +SKIP
for v in model:
    # doctest: +SKIP
    energy += model.linear[v] * sample[v]
for u, v in model.quadratic:
    # doctest: +SKIP
    energy += model.quadratic[(u, v)] * sample[u] * sample[v]
```

**Parameters**

- `sample (dict)` – Sample for which to calculate the energy, formatted as a dict where keys are variables and values are the value associated with each variable.

**Returns**

Energy for the sample.

**Return type** `float`

**Examples**

This example creates a binary quadratic model and returns the energies for a couple of samples.
```python
>>> import dimod

>>> bqm = dimod.BinaryQuadraticModel({1: 1, 2: 1}, {(1, 2): 1}, 0.5, dimod.SPIN)

>>> bqm.energy({1: -1, 2: -1})
-0.5

>>> bqm.energy({1: 1, 2: 1})
3.5
```

dimod.BinaryQuadraticModel.energies

**BinaryQuadraticModel.energies** *(samples_like, dtype='float')*

Determine the energies of the given samples.

**Parameters**

- **samples_like** *(samples_like)* – A collection of raw samples. *samples_like* is an extension of NumPy’s array_like structure. See *as_samples()*.
- **dtype** *(numpy.dtype)* – The data type of the returned energies.

**Returns**

The energies.

**Return type** *numpy.ndarray*

### Converting To and From Other Formats

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| BinaryQuadraticModel.to_coo(fp, var-
type_header) | Serialize the binary quadratic model to a COOrdinate format encoding. |
| BinaryQuadraticModel.to_ising() | Converts a binary quadratic model to Ising format. |
| BinaryQuadraticModel.to_networkx_graph(...) | Convert a binary quadratic model to NetworkX graph format. |
| BinaryQuadraticModel.to_numpy_matrix(...) | Convert a binary quadratic model to NumPy 2D array. |
| BinaryQuadraticModel.to_numpy_vectors(...) | Convert a binary quadratic model to numpy arrays. |
| BinaryQuadraticModel.to_qubo() | Convert a binary quadratic model to QUBO format. |
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**dimod.BinaryQuadraticModel.from_coo**

**classmethod** `BinaryQuadraticModel.from_coo(obj, vartype=None)`

Deserializes a binary quadratic model from a COOrdinate format encoding.

**Parameters**

- **obj** – (str/file): Either a string or a `read()`-supporting file object that represents linear and quadratic biases for a binary quadratic model. This data is stored as a list of 3-tuples, (i, j, bias), where i = j for linear biases.
- **vartype** (Vartype/str/set, optional) – Variable type for the binary quadratic model. Accepted input values:
  - `Vartype.SPIN`, 'SPIN', {-1, 1}
  - `Vartype.BINARY`, 'BINARY', {0, 1}

If not provided, the vartype must be specified with a header in the file.

**Note:** Variables must use index labels (numeric labels). Binary quadratic models created from COOrdinate format encoding have offsets set to zero.

**Examples**

An example of a binary quadratic model encoded in COOrdinate format.

```
0 0 0.50000
0 1 0.50000
1 1 -1.50000
```

The Coordinate format with a header

```
# vartype=SPIN
0 0 0.50000
0 1 0.50000
1 1 -1.50000
```

This example saves a binary quadratic model to a COOrdinate-format file and creates a new model by reading the saved file.

```python
>>> import dimod
>>> bqm = dimod.BinaryQuadraticModel({0: -1.0, 1: 1.0}, {(0, 1): -1.0}, 0.0, dimod.BINARY)
>>> with open('tmp.qubo', 'w') as file:
...     bqm.to_coo(file)
>>> with open('tmp.qubo', 'r') as file:
...     new_bqm = dimod.BinaryQuadraticModel.from_coo(file, dimod.BINARY)
>>> any(new_bqm)  # doctest: +SKIP
True
```
dimod.BinaryQuadraticModel.from_ising

classmethod BinaryQuadraticModel.from_ising(h, J, offset=0.0)
Create a binary quadratic model from an Ising problem.

Parameters

- h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form \{v: bias, ...\} where v is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.

- J (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.

- offset (optional, default=0.0) – Constant offset applied to the model.

Returns
Binary quadratic model with vartype set to Vartype.SPIN.

Return type
BinaryQuadraticModel

Examples

This example creates a binary quadratic model from an Ising problem.

```python
>>> import dimod
>>> h = {1: 1, 2: 2, 3: 3, 4: 4}
>>> J = {(1, 2): 12, (1, 3): 13, (1, 4): 14,
      ... (2, 3): 23, (2, 4): 24,
      ... (3, 4): 34}
>>> model = dimod.BinaryQuadraticModel.from_ising(h, J, offset = 0.0)
>>> model
# doctest: +SKIP
BinaryQuadraticModel({1: 1, 2: 2, 3: 3, 4: 4}, {(1, 2): 12, (1, 3): 13, (1, 4):
→14, (2, 3): 23, (2, 4): 24, (3, 4): 34, (2, 4): 24}, 0.0, Vartype.SPIN)
```

dimod.BinaryQuadraticModel.from_networkx_graph

classmethod BinaryQuadraticModel.from_networkx_graph(G,
          vartype=None,
          node_attribute_name='bias',
          edge_attribute_name='bias')

Create a binary quadratic model from a NetworkX graph.

Parameters

- G (networkx.Graph) – A NetworkX graph with biases stored as node/edge attributes.

- vartype (Vartype/str/set, optional) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

If not provided, the G should have a vartype attribute. If vartype is provided and G.vartype exists then the argument overrides the property.

- node_attribute_name (hashable, optional, default='bias') – Attribute name for linear biases. If the node does not have a matching attribute then the bias defaults to 0.

- edge_attribute_name (hashable, optional, default='bias') – Attribute name for quadratic biases. If the edge does not have a matching attribute then the bias defaults to 0.
**edge_attribute_name** *(hashable, optional, default='bias')* – Attribute name for quadratic biases. If the edge does not have a matching attribute then the bias defaults to 0.

Returns *BinaryQuadraticModel*

**Examples**

```python
>>> import networkx as nx
...
>>> G = nx.Graph()
>>> G.add_node('a', bias=.5)
>>> G.add_edge('a', 'b', bias=-1)
>>> bqm = dimod.BinaryQuadraticModel.from_networkx_graph(G, 'SPIN')
>>> bqm.adj['a']['b']
-1
```

**dimod.BinaryQuadraticModel.from_numpy_matrix**

*classmethod* `dimod.BinaryQuadraticModel.from_numpy_matrix(mat, variable_order=None, offset=0.0, interactions=None)`

Create a binary quadratic model from a NumPy array.

**Parameters**

- **mat** *(numpy.ndarray)* – Coefficients of a quadratic unconstrained binary optimization (QUBO) model formatted as a square NumPy 2D array.

- **variable_order** *(list, optional)* – If provided, labels the QUBO variables; otherwise, row/column indices are used. If `variable_order` is longer than the array, extra values are ignored.

- **offset** *(optional, default=0.0)* – Constant offset for the binary quadratic model.

- **interactions** *(iterable, optional, default=[])* – Any additional 0.0-bias interactions to be added to the binary quadratic model.

**Returns** *Binary quadratic model with vartype set to `Vartype.BINARY`.*

**Return type** `BinaryQuadraticModel`

**Examples**

This example creates a binary quadratic model from a QUBO in NumPy format while adding an interaction with a new variable ('f'), ignoring an extra variable ('g'), and setting an offset.

```python
>>> import dimod
>>> import numpy as np
...
>>> Q = np.array([[[1, 0, 0, 10, 11],
...                 [0, 2, 0, 12, 13],
...                 [0, 0, 3, 14, 15],
...                 [0, 0, 0, 4, 0],
...                 [0, 0, 0, 0, 5]]].astype(np.float32)
>>> model = dimod.BinaryQuadraticModel.from_numpy_matrix(Q,
...                                                      variable_order=['a', 'b', 'c', 'd', 'e', 'f', 'g'],
...                                                      offset=2.5,
...
```
interactions = {('a', 'f'))}
>>> model.linear  # doctest: +SKIP
{'a': 1.0, 'b': 2.0, 'c': 3.0, 'd': 4.0, 'e': 5.0, 'f': 0.0}
>>> model.quadratic[('a', 'd')] 10.0
>>> model.quadratic[('a', 'f')] 0.0
>>> model.offset 2.5

dimod.BinaryQuadraticModel.from_numpy_vectors

classmethod BinaryQuadraticModel.from_numpy_vectors(linear, quadratic, offset, vartype, variable_order=None)

Create a binary quadratic model from vectors.

Parameters

- **linear** (array_like) – A 1D array-like iterable of linear biases.
- **quadratic** (tuple[array_like, array_like, array_like]) – A 3-tuple of 1D array-like vectors of the form (row, col, bias).
- **offset** (numeric, optional) – Constant offset for the binary quadratic model.
- **vartype** (Vartype/str/set) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}
- **variable_order** (iterable, optional) – If provided, labels the variables; otherwise, indices are used.

Returns BinaryQuadraticModel

Examples

>>> import dimod
>>> import numpy as np
...
>>> linear_vector = np.asarray([-1, 1])
>>> quadratic_vectors = (np.asarray([0]), np.asarray([1]), np.asarray([-1.0]))
>>> bqm = dimod.BinaryQuadraticModel.from_numpy_vectors(linear_vector, quadratic_vectors, 0.0, dimod.SPIN)
>>> print(bqm.quadratic)
{(0, 1): -1.0}

dimod.BinaryQuadraticModel.from_qubo

classmethod BinaryQuadraticModel.from_qubo(Q, offset=0.0)

Create a binary quadratic model from a QUBO model.

Parameters
- **Q**(dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \{(u, v): bias, ...\} where u, v, are binary-valued variables and bias is their associated coefficient.

- **offset** *(optional, default=0.0)* – Constant offset applied to the model.

**Returns** Binary quadratic model with vartype set to Vartype.BINARY.

**Return type** BinaryQuadraticModel

**Examples**

This example creates a binary quadratic model from a QUBO model.

```python
>>> import dimod
>>> Q = {(0, 0): -1, (1, 1): -1, (0, 1): 2}
>>> model = dimod.BinaryQuadraticModel.from_qubo(Q, offset = 0.0)
>>> model.linear # doctest: +SKIP
{0: -1, 1: -1}
>>> model.vartype
<Vartype.BINARY: frozenset({0, 1})>
```

**dimod(BinaryQuadraticModel.from_pandas_dataframe**

**classmethod** BinaryQuadraticModel.from_pandas_dataframe(bqm_df, offset=0.0, interactions=None)

Create a binary quadratic model from a QUBO model formatted as a pandas DataFrame.

**Parameters**

- **bqm_df** *(pandas.DataFrame)* – Quadratic unconstrained binary optimization (QUBO) model formatted as a pandas DataFrame. Row and column indices label the QUBO variables; values are QUBO coefficients.

- **offset** *(optional, default=0.0)* – Constant offset for the binary quadratic model.

- **interactions** *(iterable, optional, default=[])* – Any additional 0.0-bias interactions to be added to the binary quadratic model.

**Returns** Binary quadratic model with vartype set to vartype.BINARY.

**Return type** BinaryQuadraticModel

**Examples**

This example creates a binary quadratic model from a QUBO in pandas DataFrame format while adding an interaction and setting a constant offset.

```python
>>> import dimod
>>> import pandas as pd
>>> pd_qubo = pd.DataFrame(data={0: [-1, 0], 1: [2, -1]})
>>> model = dimod.BinaryQuadraticModel.from_pandas_dataframe(pd_qubo, ...
... offset = 2.5,
```

(continues on next page)
... interactions = {(0, 2), (1, 2)}
>>> model.linear  # doctest: +SKIP
{0: -1, 1: -1.0, 2: 0.0}
>>> model.quadratic  # doctest: +SKIP
{(0, 1): 2, (0, 2): 0.0, (1, 2): 0.0}
>>> model.offset
2.5
>>> model.vartype
<Vartype.BINARY: frozenset({0, 1})>

dimod.BinaryQuadraticModel.from_serializable

class method BinaryQuadraticModel.from_serializable(obj)
Deserialize a binary quadratic model.

Parameters
obj (dict) – A binary quadratic model serialized by to_serializable().

Returns
BinaryQuadraticModel

Examples

Encode and decode using JSON

>>> import dimod
>>> import json
... >>> bqm = dimod.BinaryQuadraticModel({'a': -1.0, 'b': 1.0}, {('a', 'b'): -1.0}, 0., dimod.SPIN)
>>> s = json.dumps(bqm.to_serializable())
>>> new_bqm = dimod.BinaryQuadraticModel.from_serializable(json.loads(s))

See also:
to_serializable()
json.loads(), json.load() JSON deserialization functions

dimod.BinaryQuadraticModel.to_coo

BinaryQuadraticModel.to_coo(fp=None, vartype_header=False)
Serialize the binary quadratic model to a COOrdinate format encoding.

Parameters

• fp (file, optional) – .write()-supporting file object to save the linear and quadratic biases of a binary quadratic model to. The model is stored as a list of 3-tuples, (i, j, bias), where i = j for linear biases. If not provided, returns a string.

• vartype_header (bool, optional, default=False) – If true, the binary quadratic model’s variable type as prepended to the string or file as a header.

Note: Variables must use index lables (numeric lables). Binary quadratic models saved to COOrdinate format encoding do not preserve offsets.
Examples

This is an example of a binary quadratic model encoded in COOrdinate format.

```
0 0 0.50000
0 1 0.50000
1 1 -1.50000
```

The Coordinate format with a header

```
# vartype=SPIN
0 0 0.50000
0 1 0.50000
1 1 -1.50000
```

This is an example of writing a binary quadratic model to a COOrdinate-format file.

```
>>> bqm = dimod.BinaryQuadraticModel({0: -1.0, 1: 1.0}, {(0, 1): -1.0}, 0.0, dimod.SPIN)
>>> with open('tmp.ising', 'w') as file:    # doctest: +SKIP
    ...  bqm.to_coo(file)
```

This is an example of writing a binary quadratic model to a COOrdinate-format string.

```
>>> bqm = dimod.BinaryQuadraticModel({0: -1.0, 1: 1.0}, {(0, 1): -1.0}, 0.0, dimod.SPIN)
>>> bqm.to_coo()    # doctest: +SKIP
0 0 -1.000000
0 1 -1.000000
1 1 1.000000
```

dimod.BinaryQuadraticModel.to_ising

```
BinaryQuadraticModel.to_ising()  
Converts a binary quadratic model to Ising format.

If the binary quadratic model’s vartype is not Vartype.SPIN, values are converted.

Returns 3-tuple of form (linear, quadratic, offset), where linear is a dict of linear biases, quadratic is a dict of quadratic biases, and offset is a number that represents the constant offset of the binary quadratic model.

Return type tuple
```

Examples

This example converts a binary quadratic model to an Ising problem.

```
>>> import dimod
>>> model = dimod.BinaryQuadraticModel({0: 1, 1: -1, 2: .5},
    ...
    {0, 1): .5, (1, 2): 1.5},
    ...
    1.4,
    ...
    dimod.SPIN)
>>> model.to_ising()    # doctest: +SKIP
({0: 1, 1: -1, 2: 0.5}, {0, 1): 0.5, (1, 2): 1.5}, 1.4)
dimod Documentation, Release 0.8.21

dimod.BinaryQuadraticModel.to_networkx_graph

BinaryQuadraticModel.to_networkx_graph(node_attribute_name='bias',
edge_attribute_name='bias')
Convert a binary quadratic model to NetworkX graph format.

Parameters

• **node_attribute_name** (hashable, optional, default='bias') – Attribute name for linear biases.

• **edge_attribute_name** (hashable, optional, default='bias') – Attribute name for quadratic biases.

Returns A NetworkX graph with biases stored as node/edge attributes.

Return type networkx.Graph

Examples

This example converts a binary quadratic model to a NetworkX graph, using first the default attribute name for quadratic biases then “weight”.

```python
>>> import networkx as nx
>>> bqm = dimod.BinaryQuadraticModel({0: 1, 1: -1, 2: .5},
...   {(0, 1): .5, (1, 2): 1.5},
...   1.4,
...   dimod.SPIN)
>>> BQM = bqm.to_networkx_graph()
>>> BQM[0][1]['bias']
0.5
>>> BQM.node[0]['bias']
1
>>> BQM_w = bqm.to_networkx_graph(edge_attribute_name='weight')
>>> BQM_w[0][1]['weight']
0.5
```

dimod.BinaryQuadraticModel.to_numpy_matrix

BinaryQuadraticModel.to_numpy_matrix(variable_order=None)
Convert a binary quadratic model to NumPy 2D array.

Parameters **variable_order** (list, optional) – If provided, indexes the rows/columns of the NumPy array. If variable_order includes any variables not in the binary quadratic model, these are added to the NumPy array.

Returns The binary quadratic model as a NumPy 2D array. Note that the binary quadratic model is converted to BINARY vartype.

Return type numpy.ndarray

Notes

The matrix representation of a binary quadratic model only makes sense for binary models. For a binary sample \(x\), the energy of the model is given by:

\[ E(x) = x^T Q x \]
The offset is dropped when converting to a NumPy array.

**Examples**

This example converts a binary quadratic model to NumPy array format while ordering variables and adding one (’d’).

```python
>>> import dimod
>>> import numpy as np
...
>>> model = dimod.BinaryQuadraticModel({'a': 1, 'b': -1, 'c': .5},
...    {('a', 'b'): .5, ('b', 'c'): 1.5},
...    1.4,
...    dimod.BINARY)
>>> model.to_numpy_matrix(variable_order=['d', 'c', 'b', 'a'])
array([[ 0., 0., 0., 0.],
       [ 0., 0.5, 1.5, 0. ],
       [ 0., 0., -1., 0.5],
       [ 0., 0., 0., 1. ]])
```

**dimod.BinaryQuadraticModel.to_numpy_vectors**

`BinaryQuadraticModel.to_numpy_vectors`(`variable_order=None, dtype=<class 'float'>, index_dtype=<class 'numpy.int64'>, sort_indices=False)

Convert a binary quadratic model to numpy arrays.

**Parameters**

- **variable_order** (iterable, optional) – If provided, labels the variables; otherwise, row/column indices are used.
- **dtype** (numpy.dtype, optional) – Data-type of the biases. By default, the data-type is inferred from the biases.
- **index_dtype** (numpy.dtype, optional) – Data-type of the indices. By default, the data-type is inferred from the labels.
- **sort_indices** (bool, optional, default=False) – If True, the indices are sorted, first by row then by column. Otherwise they match quadratic.

**Returns**

A numpy array of the linear biases.

tuple: The quadratic biases in COOrdinate format.

- **ndarray** A numpy array of the row indices of the quadratic matrix entries
- **ndarray** A numpy array of the column indices of the quadratic matrix entries
- **ndarray** A numpy array of the values of the quadratic matrix entries

The offset

**Return type** ndarray
Examples

```python
generate example code here
```

dimod.BinaryQuadraticModel.to_qubo

BinaryQuadraticModel.to_qubo()

Convert a binary quadratic model to QUBO format.

If the binary quadratic model’s vartype is not Vartype.BINARY, values are converted.

Returns 2-tuple of form (biases, offset), where biases is a dict in which keys are pairs of variables and values are the associated linear or quadratic bias and offset is a number that represents the constant offset of the binary quadratic model.

Return type tuple

Examples

This example converts a binary quadratic model with spin variables to QUBO format with binary variables.

```python
generate example code here
```

dimod.BinaryQuadraticModel.to_pandas_dataframe

BinaryQuadraticModel.to_pandas_dataframe()

Convert a binary quadratic model to pandas DataFrame format.

Returns The binary quadratic model as a DataFrame. The DataFrame has binary vartype. The rows and columns are labeled by the variables in the binary quadratic model.

Return type pandas.DataFrame
Notes

The DataFrame representation of a binary quadratic model only makes sense for binary models. For a binary sample \(x\), the energy of the model is given by:

\[
E(x) = x^TQx
\]

The offset is dropped when converting to a pandas DataFrame.

Examples

This example converts a binary quadratic model to pandas DataFrame format.

```python
>>> import dimod
... model = dimod.BinaryQuadraticModel({'a': 1.1, 'b': -1., 'c': .5},
...       {('a', 'b'): .5, ('b', 'c'): 1.5},
...       1.4,
...       dimod.BINARY)
... model.to_pandas_dataframe()  # doctest: +SKIP
   a  b  c
a  1.1 0.5 0.0
b  0.0 -1.0 1.5
c  0.0 0.0 0.5
```

dimod.BinaryQuadraticModel.to_serializable

BinaryQuadraticModel.to_serializable(use_bytes=False, bias_dtypes=<class 'numpy.float32'>, bytes_type=<class 'bytes'>)

Convert the binary quadratic model to a serializable object.

Parameters

- **use_bytes** (bool, optional, default=False) – If True, a compact representation representing the biases as bytes is used. Uses tobytes().

- **bias_dtypes** (data-type, optional, default=numpy.float32) – If use_bytes is True, this dtype will be used to represent the bias values in the serialized format.

- **bytes_type** (class, optional, default=bytes) – This class will be used to wrap the bytes objects in the serialization if use_bytes is true. Useful for when using Python 2 and using BSON encoding, which will not accept the raw bytes type, so bson.Binary can be used instead.

Returns

An object that can be serialized.

Return type

dict

Examples

Encode using JSON

```python
>>> import dimod
... >>> import json
... ... # doctest: +SKIP
```
Encode using **BSON** in python 3.5+

```python
>>> import dimod
>>> import bson
...
>>> bqm = dimod.BinaryQuadraticModel({"a": -1.0, "b": 1.0}, {("a", "b"): -1.0}, 0., dimod.SPIN)
>>> doc = bqm.to_serializable(use_bytes=True)
>>> b = bson.BSON.encode(doc)  # doctest: +SKIP
```

Encode using BSON in python 2.7. Because `bytes` is an alias for `str`, we need to signal to the encoder that it should encode the biases and labels as binary data.

```python
>>> import dimod
>>> import bson
...
>>> bqm = dimod.BinaryQuadraticModel({"a": -1.0, "b": 1.0}, {("a", "b"): -1.0}, 0., dimod.SPIN)
>>> doc = bqm.to_serializable(use_bytes=True, bytes_type=bson.Binary)
>>> b = bson.BSON.encode(doc)  # doctest: +SKIP
```

See also:
- `from_serializable()`
- `json.dumps()`, `json.dump()` JSON encoding functions
- `bson.BSON.encode()` BSON encoding method

**Alias**

**BQM**

Alias for `BinaryQuadraticModel`

alias of `dimod.binary_quadratic_model.BinaryQuadraticModel`

**BQM Generators**

**Chimera Structured**

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<th>chimera_anticluster(m[, n, t, multiplier, ...])</th>
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<table>
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<th>dimod.generators.chimera.chimera_anticluster</th>
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chimera_anticluster\(m, \ n=\text{None}, \ i=4, \ \text{multiplier}=3.0, \ \text{cls}=<\text{class} \ 'di-mod.binary_quadratic_model.BinaryQuadraticModel'>, \ \text{subgraph}=\text{None}, \ \text{seed}=\text{None})

Generate an anticluster problem on a Chimera lattice.

An anticluster problem has weak interactions within a tile and strong interactions between tiles.
Parameters

- **m** (*int*) – Number of rows in the Chimera lattice.
- **n** (*int*, optional, default=m) – Number of columns in the Chimera lattice.
- **t** (*int*, optional, default=t) – Size of the shore within each Chimera tile.
- **multiplier** (*number*, optional, default=3.0) – Strength of the intertile edges.
- **cls** (class, optional, default=:`class:.BinaryQuadraticModel`) – Binary quadratic model class to build from.
- **subgraph** (int/tuple[nodes, edges]/list[edge]/`Graph`) – A subgraph of a Chimera(m, n, t) graph to build the anticluster problem on.
- **seed** (*int*, optional, default=None) – Random seed.

Returns spin-valued binary quadratic model.

Return type `BinaryQuadraticModel`

Constraints

**combinations(n, k[, strength, vartype])**
Generate a bqm that is minimized when k of n variables are selected.

dimod.generators.constraints.combinations

**combinations** (*n, k, strength=1, vartype=<Vartype.BINARY: frozenset({0, 1})>)*
Generate a bqm that is minimized when k of n variables are selected.

More fully, we wish to generate a binary quadratic model which is minimized for each of the k-combinations of its variables.

The energy for the binary quadratic model is given by \((\sum_i x_i - k)^2\).

Parameters

- **n** (*int/list/set*) – If n is an integer, variables are labelled [0, n-1]. If n is list or set then the variables are labelled accordingly.
- **k** (*int*) – The generated binary quadratic model will have 0 energy when any k of the variables are 1.
- **strength** (*number*, optional, default=1) – The energy of the first excited state of the binary quadratic model.
- **vartype** (*Vartype/str/set*) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

Returns `BinaryQuadraticModel`
Examples

```python
>>> bqm = dimod.generators.combinations(['a', 'b', 'c'], 2)
>>> bqm.energy({'a': 1, 'b': 0, 'c': 1})
0.0
>>> bqm.energy({'a': 1, 'b': 1, 'c': 1})
1.0
```

```python
>>> bqm = dimod.generators.combinations(5, 1)
>>> bqm.energy({0: 0, 1: 0, 2: 1, 3: 0, 4: 0})
0.0
>>> bqm.energy({0: 0, 1: 0, 2: 1, 3: 1, 4: 0})
1.0
```

```python
>>> bqm = dimod.generators.combinations(['a', 'b', 'c'], 2, strength=3.0)
>>> bqm.energy({'a': 1, 'b': 0, 'c': 1})
0.0
>>> bqm.energy({'a': 1, 'b': 1, 'c': 1})
3.0
```

Frustrated Cluster Loops

`frustrated_loop(graph, num_cycles[, R, ...])` Generate a frustrated loop problem.

dimod.generators.fcl.frustrated_loop

`frustrated_loop(graph, num_cycles, R=inf, cycle_predicates=(), max_failed_cycles=100, seed=None)` Generate a frustrated loop problem.

A (generic) frustrated loop (FL) problem is a sum of Hamiltonians, each generated from a single “good” loop.

1. Generate a loop by random walking on the support graph.
2. If the cycle is “good” (according to provided predicates), continue, else go to 1.
3. Choose one edge of the loop to be anti-ferromagnetic; all other edges are ferromagnetic.
4. Add the loop’s coupler values to the FL problem. If at any time the magnitude of a coupler in the FL problem exceeds a given precision $R$, remove that coupler from consideration in the loop generation procedure.

This is a generic generator of FL problems that encompasses both the original FL problem definition from\(^1\) and the limited FL problem definition from\(^2\)

Parameters

- `graph` (int/tuple[nodes, edges]/list[edge]/Graph) – The graph to build the frustrated loops on. Either an integer $n$, interpreted as a complete graph of size $n$, a nodes/edges pair, a list of edges or a NetworkX graph.
- `num_cycles` (int) – Desired number of frustrated cycles.
- `R` (int, optional, default=inf) – Maximum interaction weight.
- `cycle_predicates` (tuple[function], optional) – An iterable of functions, which should accept a cycle and return a bool.

---


• **max_failed_cycles**(int, optional, default=100) – Maximum number of failures to find a cycle before terminating.

• **seed**(int, optional, default=None) – Random seed.

### Random

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<td>uniform</td>
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</table>

**dimod.generators.random.randint**

**randint**(graph, vartype[, low, high, cls, seed])

Generate a bqm with random biases and offset.

Biases and offset are integer-valued in range [low, high] inclusive.

**Parameters**

- **graph**(int/tuple[nodes, edges]/list[edge]/Graph) – The graph to build the bqm on. Either an integer n, interpreted as a complete graph of size n, a nodes/edges pair, a list of edges or a NetworkX graph.

- **vartype**(Vartype/str/set) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

- **low**(float, optional, default=0) – The low end of the range for the random biases.

- **high**(float, optional, default=1) – The high end of the range for the random biases.

- **cls**(BinaryQuadraticModel) – Binary quadratic model class to build from.

- **seed**(int, optional, default=None) – Random seed.

**Returns** BinaryQuadraticModel

**dimod.generators.random.ran_r**

**ran_r**(r, graph[, cls, seed])

Generate an Ising model for a RANr problem.

In RANr problems all linear biases are zero and quadratic values are uniformly selected integers between -r to r, excluding zero. This class of problems is relevant for binary quadratic models (BQM) with spin variables (Ising models).

This generator of RANr problems follows the definition in [Kin2015].

**Parameters**

- **r**(int) – Order of the RANr problem.
dimod Documentation, Release 0.8.21

- **graph** (int/tuple[nodes, edges]/list[edge]/Graph) – The graph to build the bqm on. Either an integer n, interpreted as a complete graph of size n, a nodes/edges pair, a list of edges or a NetworkX graph.

- **cls** (BinaryQuadraticModel) – Binary quadratic model class to build from.

- **seed** (int, optional, default=None) – Random seed.

Returns BinaryQuadraticModel.

Examples:

```python
>>> import networkx as nx
>>> K_7 = nx.complete_graph(7)
>>> bqm = dimod.generators.random.ran_r(1, K_7)
```

dimod.generators.random.uniform

**uniform** (graph, vartype, low=0.0, high=1.0, cls=BinaryQuadraticModel, seed=None)

Generate a bqm with random biases and offset.

Biases and offset are drawn from a uniform distribution range (low, high).

Parameters

- **graph** (int/tuple[nodes, edges]/list[edge]/Graph) – The graph to build the bqm on. Either an integer n, interpreted as a complete graph of size n, a nodes/edges pair, a list of edges or a NetworkX graph.

- **vartype** (Vartype/str/set) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

- **low** (float, optional, default=0.0) – The low end of the range for the random biases.

- **high** (float, optional, default=1.0) – The high end of the range for the random biases.

- **cls** (BinaryQuadraticModel) – Binary quadratic model class to build from.

- **seed** (int, optional, default=None) – Random seed.

Returns BinaryQuadraticModel

**BQM Functions**

Functional interface to BQM methods and assorted utilities.

**Roof-duality**

| fix_variables(bqm[, sampling_mode]) | Determine assignments for some variables of a binary quadratic model. |
dimod.roof_duality.fix_variables

**fix_variables** (*bqm, sampling_mode=True*)

Determine assignments for some variables of a binary quadratic model.

Roof duality finds a lower bound for the minimum of a quadratic polynomial. It can also find minimizing assignments for some of the polynomial’s variables; these fixed variables take the same values in all optimal solutions [BHT] [BH]. A quadratic pseudo-Boolean function can be represented as a network to find the lower bound through network-flow computations. **fix_variables** uses maximum flow in the implication network to correctly fix variables. Consequently, you can find an assignment for the remaining variables that attains the optimal value.

**Parameters**

- **bqm** (*BinaryQuadraticModel*) – A binary quadratic model.

- **sampling_mode** (*bool, optional, default=True*) – In sampling mode, only roof-duality is used. When **sampling_mode** is false, strongly connected components are used to fix more variables, but in some optimal solutions these variables may take different values.

**Returns**

Variable assignments for some variables of the specified binary quadratic model.

**Return type** *dict*

**Examples**

This example creates a binary quadratic model with a single ground state and fixes the model’s single variable to the minimizing assignment.

```python
>>> bqm = dimod.BinaryQuadraticModel.empty(dimod.SPIN)
>>> bqm.add_variable('a', 1.0)
>>> dimod.fix_variables(bqm)
{'a': -1}
```

This example has two ground states, \(a = b = -1\) and \(a = b = 1\), with no variable having a single value for all ground states, so neither variable is fixed.

```python
>>> bqm = dimod.BinaryQuadraticModel.empty(dimod.SPIN)
>>> bqm.add_interaction('a', 'b', -1.0)
>>> dimod.fix_variables(bqm) # doctest: +SKIP
{}
```

This example turns sampling model off, so variables are fixed to an assignment that attains the ground state.

```python
>>> bqm = dimod.BinaryQuadraticModel.empty(dimod.SPIN)
>>> bqm.add_interaction('a', 'b', -1.0)
>>> dimod.fix_variables(bqm, sampling_mode=False) # doctest: +SKIP
{'a': 1, 'b': 1}
```

**Traversal**

<table>
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<td>Yields sets of connected variables.</td>
</tr>
<tr>
<td><strong>bfs_variables</strong>(bqm, source)</td>
<td>Yields variables in breadth-first search order.</td>
</tr>
</tbody>
</table>
dimod.traversal.connected_components

`connected_components(bqm)`
Yields sets of connected variables.

**Parameters**
- `bqm (dimod.BinaryQuadraticModel)` – A binary quadratic model.

**Yields**
- `set` – A set of variables in the `bqm` that form a connected component.

dimod.traversal.bfs_variables

`bfs_variables(bqm, source)`
Yields variables in breadth-first search order.

**Parameters**
- `bqm (dimod.BinaryQuadraticModel)` – A binary quadratic model.
- `source (variable)` – A variable in the binary quadratic model.

**Yields**
- `variable` – variables in the `bqm`, yielded in breadth-first search order starting at `source`.

2.2.2 Samplers and Composites

Samplers

The `dimod` package includes several example samplers.

Contents

- *Samplers*
  - *Exact Solver*
    - *Class*
    - *Methods*
  - *Null Sampler*
    - *Class*
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  - *Random Sampler*
    - *Class*
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  - *Simulated Annealing Sampler*
    - *Class*
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Exact Solver

A solver that calculates the energy of all possible samples.

**Note:** This sampler is designed for use in testing. Because it calculates the energy for every possible sample, it is very slow.

Class

class ExactSolver

A simple exact solver for testing and debugging code using your local CPU.

Notes

This solver becomes slow for problems with 18 or more variables.

Examples

This example solves a two-variable Ising model.

```python
>>> h = {'a': -0.5, 'b': 1.0}
>>> J = {('a', 'b'):-1.5}
>>> sampleset = dimod.ExactSolver().sample_ising(h, J)
>>> print(sampleset)
a b energy num_oc.
0 -1 -1 -2.0 1
2 +1 +1 -1.0 1
1 +1 -1 0.0 1
3 -1 +1 3.0 1
['SPIN', 4 rows, 4 samples, 2 variables]
```

This example solves a two-variable QUBO.

```python
>>> Q = {('a', 'b'): 2.0, ('a', 'a'): 1.0, ('b', 'b'): -0.5}
>>> sampleset = dimod.ExactSolver().sample_qubo(Q)
```

This example solves a two-variable binary quadratic model

```python
>>> bqm = dimod.BinaryQuadraticModel({'a': 1.5}, {('a', 'b'): -1}, 0.0, 'SPIN')
>>> sampleset = dimod.ExactSolver().sample(bqm)
```

Methods

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<tr>
<th>Method</th>
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<tr>
<td><code>ExactSolver.sample(bqm)</code></td>
<td>Sample from a binary quadratic model.</td>
</tr>
<tr>
<td><code>ExactSolver.sample_ising(h, J, **parameters)</code></td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td><code>ExactSolver.sample_qubo(Q, **parameters)</code></td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
ExactSolver.sample(bqm)
Sample from a binary quadratic model.

Parameters
bqm (BinaryQuadraticModel) – Binary quadratic model to be sampled from.

Returns SampleSet

ExactSolver.sample_ising(h, J, **parameters)
Sample from an Ising model using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters
• h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form {v: bias, ...} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
• J (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_qubo()

ExactSolver.sample_qubo(Q, **parameters)
Sample from a QUBO using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters
• Q (dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form {(u, v): bias, ...} where u, v, are binary-valued variables and bias is their associated coefficient.
• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_ising()
**Null Sampler**

A sampler that always returns an empty sample set.

**Class**

```python
class NullSampler(parameters=None)
A sampler that always returns an empty sample set.
This sampler is useful for writing unit tests where the result is not important.

Parameters `parameters` (iterable/dict, optional) – If provided, sets the parameters accepted by the sample methods. The values given in these parameters are ignored.
```

**Examples**

```python
>>> bqm = dimod.BinaryQuadraticModel.from_qubo({('a', 'b'): 1})
>>> sampler = dimod.NullSampler()
>>> sampleset = sampler.sample(bqm)
>>> len(sampleset)
0
```

Setting additional parameters for the null sampler.

```python
>>> bqm = dimod.BinaryQuadraticModel.from_qubo({('a', 'b'): 1})
>>> sampler = dimod.NullSampler(parameters=['a'])
>>> sampleset = sampler.sample(bqm, a=5)
```

**Properties**

<table>
<thead>
<tr>
<th><code>NullSampler.parameters</code></th>
<th>Keyword arguments accepted by the sampling methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>dimod.reference.samplers.null_sampler.NullSampler.parameters</strong></td>
<td></td>
</tr>
</tbody>
</table>

`NullSampler.parameters = None`
Keyword arguments accepted by the sampling methods

**Methods**

<table>
<thead>
<tr>
<th><code>NullSampler.sample(bqm, **kwargs)</code></th>
<th>Return an empty sample set.</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>NullSampler.sample_ising(h, J, **parameters)</code></td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td><code>NullSampler.sample_qubo(Q, **parameters)</code></td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
**dimod.reference.samplers.null_sampler.NullSampler.sample**

```python
null_sampler.sample(bqm, **kwargs)
```

Return an empty sample set.

**Parameters**

- `bqm (BinaryQuadraticModel)` – The binary quadratic model determines the variables labels in the sample set.
- `kwargs` – As specified when constructing the null sampler.

**Returns**
The empty sample set.

**Return type**
`SampleSet`

**dimod.reference.samplers.null_sampler.NullSampler.sample_ising**

```python
null_sampler.sample_ising(h, J, **parameters)
```

Sample from an Ising model using the implemented sample method.

This method is inherited from the `Sampler` base class.

Converts the Ising model into a `BinaryQuadraticModel` and then calls `sample()`.

**Parameters**

- `h (dict/list)` – Linear biases of the Ising problem. If a dict, should be of the form `{v: bias, ...}` where is a spin-valued variable and `bias` is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- `J (dict[(variable, variable), bias])` – Quadratic biases of the Ising problem.
- `**kwargs` – See the implemented sampling for additional keyword definitions.

**Returns**
`SampleSet`

See also:
`sample()`, `sample_qubo()`

**dimod.reference.samplers.null_sampler.NullSampler.sample_qubo**

```python
null_sampler.sample_qubo(Q, **parameters)
```

Sample from a QUBO using the implemented sample method.

This method is inherited from the `Sampler` base class.

Converts the QUBO into a `BinaryQuadraticModel` and then calls `sample()`.

**Parameters**

- `Q (dict)` – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form `{(u, v): bias, ...}` where `u, v` are binary-valued variables and `bias` is their associated coefficient.
- `**kwargs` – See the implemented sampling for additional keyword definitions.

**Returns**
`SampleSet`
See also:

sample(), sample_ising()

Random Sampler

A sampler that gives random samples.

Class

class RandomSampler

A sampler that gives random samples for testing.

Properties

RandomSampler.parameters

Keyword arguments accepted by the sampling methods.

dimod.reference.samplers.random_sampler.RandomSampler.parameters

RandomSampler.parameters = None

Keyword arguments accepted by the sampling methods.

Contents are exactly {'num_reads': []}

Type dict

Methods

RandomSampler.sample(bqm[, num_reads])

Give random samples for a binary quadratic model.

Variable assignments are chosen by coin flip.

Parameters

• bqm (BinaryQuadraticModel) – Binary quadratic model to be sampled from.

• num_reads (int, optional, default=10) – Number of reads.

Returns SampleSet

RandomSampler.sample_ising(h, J, **parameters)

Sample from an Ising model using the implemented sample method.

dimod.reference.samplers.random_sampler.RandomSampler.sample_qubo(Q, **parameters)

Sample from a QUBO using the implemented sample method.
RandomSampler.sample_ising \((h, J, **\text{parameters})\)
Sample from an Ising model using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters

- \(h\) (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form \(\{v: \text{bias}, \ldots\}\) where \(v\) is a spin-valued variable and \(\text{bias}\) is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- \(J\) (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
- \(**\text{kwargs}\) – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_qubo()

dimod.reference.samplers.random_sampler.RandomSampler.sample_qubo

RandomSampler.sample_qubo \((Q, **\text{parameters})\)
Sample from a QUBO using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

- \(Q\) (dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \(\{(u, v): \text{bias}, \ldots\}\) where \(u, v\) are binary-valued variables and \(\text{bias}\) is their associated coefficient.
- \(**\text{kwargs}\) – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_ising()
Examples

This example solves a two-variable Ising model.

```python
>>> h = {'a': -0.5, 'b': 1.0}
>>> J = {('a', 'b'): -1.5}
>>> sampleset = dimod.SimulatedAnnealingSampler().sample_ising(h, J)
```

Properties

<table>
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<th><code>SimulatedAnnealingSampler.parameters</code></th>
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<td></td>
</tr>
<tr>
<td><code>SimulatedAnnealingSampler.parameters</code></td>
<td><code>None</code></td>
</tr>
<tr>
<td></td>
<td>Keyword arguments accepted by the sampling methods.</td>
</tr>
<tr>
<td></td>
<td>Contents are exactly <code>{'beta_range': [], 'num_reads': [], 'num_sweeps': []}</code></td>
</tr>
<tr>
<td></td>
<td>Type</td>
</tr>
</tbody>
</table>

Methods

| `SimulatedAnnealingSampler.sample(bqm[, ...])` | Sample from low-energy spin states using simulated annealing. |
| `SimulatedAnnealingSampler.sample_ising(h, J[, ...])` | Sample from an Ising model using the implemented sample method. |
| `SimulatedAnnealingSampler.sample_qubo(Q[, ...])` | Sample from a QUBO using the implemented sample method. |

<table>
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<tr>
<th><code>dimod.reference.samplers.simulated_annealing.SimulatedAnnealingSampler.sample</code></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><code>SimulatedAnnealingSampler.sample(bqm[, beta_range=None, num_reads=10, num_sweeps=1000])</code></td>
<td>Sample from low-energy spin states using simulated annealing.</td>
</tr>
</tbody>
</table>

Parameters

- `bqm (BinaryQuadraticModel)` - Binary quadratic model to be sampled from.
- `beta_range (tuple, optional)` - Beginning and end of the beta schedule (beta is the inverse temperature) as a 2-tuple. The schedule is applied linearly in beta. Default is chosen based on the total bias associated with each node.
- `num_reads (int, optional, default=10)` - Number of reads. Each sample is the result of a single run of the simulated annealing algorithm.
- `num_sweeps (int, optional, default=1000)` - Number of sweeps or steps.

Returns `SampleSet`

Note: This is a reference implementation, not optimized for speed and therefore not an appropriate sampler for
SimulatedAnnealingSampler` .`sample_ising` (`h, J, **parameters`) 
Sample from an Ising model using the implemented sample method.

This method is inherited from the `Sampler` base class.

Converts the Ising model into a `BinaryQuadraticModel` and then calls `sample()`.

Parameters

- `h (dict/list)` – Linear biases of the Ising problem. If a dict, should be of the form `{v: bias, ...}` where `v` is a spin-valued variable and `bias` is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- `J (dict[(variable, variable), bias])` – Quadratic biases of the Ising problem.
- `**kwargs` – See the implemented sampling for additional keyword definitions.

Returns `SampleSet`

See also:
`sample()`, `sample_qubo()`

SimulatedAnnealingSampler` .`sample_qubo` (`Q, **parameters`) 
Sample from a QUBO using the implemented sample method.

This method is inherited from the `Sampler` base class.

Converts the QUBO into a `BinaryQuadraticModel` and then calls `sample()`.

Parameters

- `Q (dict)` – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form `{(u, v): bias, ...}` where `u, v` are binary-valued variables and `bias` is their associated coefficient.
- `**kwargs` – See the implemented sampling for additional keyword definitions.

Returns `SampleSet`

See also:
`sample()`, `sample_ising()`

Composites

The `dimod` package includes several example composed samplers.
Connected Components Composite

A composite that breaks the problem into sub-problems corresponding to the connected components of the binary quadratic model graph before sending to its child sampler.

Class

class ConnectedComponentsComposite(child_sampler)

Composite to decompose a problem to the connected components and solve each.

Connected components of a bqm graph are computed (if not provided), and each subproblem is passed to the child sampler. Returned samples from each child sampler are merged. Only the best solution of each response is pick and merge with others (i.e. this composite returns a single solution).

Parameters

sampler(dimod.Sampler) – A dimod sampler

Examples

This example uses ConnectedComponentsComposite to instantiate a composed sampler that submits a simple Ising problem to a sampler. The composed sampler finds the connected components and solves each.

```python
>>> h = {1: -1.3, 2: 2.3, 3:-1.2, 4: -0.5}
>>> J = {(1, 4): -0.6, (1, 3): 0.6, (3, 4): 1.0, (2, 3): -1.0}

>>> sampler = dimod.ConnectedComponentsComposite(dimod.ExactSolver())

>>> sampleset = sampler.sample_ising(h, J)
```

Properties

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<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>ConnectedComponentsComposite.child</td>
<td>The child sampler.</td>
</tr>
<tr>
<td>ConnectedComponentsComposite.children</td>
<td>List of child samplers that that are used by this composite.</td>
</tr>
<tr>
<td>ConnectedComponentsComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.</td>
</tr>
<tr>
<td>ConnectedComponentsComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.child

ConnectedComponentsComposite.child

The child sampler. First sampler in Composite.children.

Type: Sampler

dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.children

ConnectedComponentsComposite.children

List of child samplers that that are used by this composite.

Type: list[Sampler]
dimod Documentation, Release 0.8.21

**dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.parameters**

**ConnectedComponentsComposite.parameters**

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

**Type**  dict

**dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.properties**

**ConnectedComponentsComposite.properties**

A dict containing any additional information about the sampler.

**Type**  dict

**Methods**

<table>
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<th>Description</th>
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<tbody>
<tr>
<td>ConnectedComponentsComposite.sample(bqm[, ...])</td>
<td>Sample from the provided binary quadratic model.</td>
</tr>
<tr>
<td>ConnectedComponentsComposite.sample_ising(h, ...)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>ConnectedComponentsComposite.sample_qubo(Q, ...)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>

**dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.sample**

**ConnectedComponentsComposite.sample(bqm, components=None, **parameters)**

Sample from the provided binary quadratic model.

**Parameters**

- **bqm** *(dimod.BinaryQuadraticModel)* – Binary quadratic model to be sampled from.
- **components** *(list(set))* – A list of disjoint set of variables that fully partition the variables
- ****parameters** – Parameters for the sampling method, specified by the child sampler.

**Returns**  dimod.SampleSet

**dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.sample_ising**

**ConnectedComponentsComposite.sample_ising(h, J, **parameters)**

Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().

**Parameters**

- **h** *(dict/list)* – Linear biases of the Ising problem. If a dict, should be of the form `{v: bias, ...}` where `v` is a spin-valued variable and `bias` is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
• $J(dict[(variable, variable), bias])$ – Quadratic biases of the Ising problem.

• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_qubo()

dimod.reference.composites.connectedcomponent.ConnectedComponentsComposite.sample_qubo

ConnectedComponentsComposite.sample_qubo($Q$, **parameters)
Sample from a QUBO using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

• $Q(dict)$ – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form $\{(u, v): bias, \ldots\}$ where $u, v$, are binary-valued variables and bias is their associated coefficient.

• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:
sample(), sample_ising()

Clip Composite

A composite that clips problem variables below and above threshold. If lower and upper bounds is not given it does nothing.

Class

class ClipComposite(child_sampler)
Composite to clip variables of a problem

Clips the variables of a bqm and modifies linear and quadratic terms accordingly.

Parameters sampler(dimod.Sampler) – A dimod sampler

Examples

This example uses ClipComposite to instantiate a composed sampler that submits a simple Ising problem to a sampler. The composed sampler clips linear and quadratic biases as indicated by options.

```python
>>> h = {'a': -4.0, 'b': -4.0}
>>> J = {('a', 'b'): 3.2}
>>> sampler = dimod.ClipComposite(dimod.ExactSolver())
>>> response = sampler.sample_ising(h, J, lower_bound=-2.0, upper_bound=2.0)
```
Properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClipComposite.children</td>
<td>List of child samplers that are used by this composite.</td>
</tr>
<tr>
<td>ClipComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>ClipComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClipComposite.sample(bqm[, lower_bound, ...])</td>
<td>Clip and sample from the provided binary quadratic model.</td>
</tr>
<tr>
<td>ClipComposite.sample_ising(h, J, **parameters)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>ClipComposite.sample_qubo(Q, **parameters)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
dimod.reference.composites.clipcomposite.ClipComposite.sample

ClipComposite.sample(bqm, lower_bound=None, upper_bound=None, **parameters)

Clip and sample from the provided binary quadratic model.

If lower_bound and upper_bound are given variables with value above or below are clipped.

Parameters

- **bqm** (dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from.
- **lower_bound** (number) – Value by which to clip the variables from below.
- **upper_bound** (number) – Value by which to clip the variables from above.
- ****parameters – Parameters for the sampling method, specified by the child sampler.

Returns dimod.SampleSet

dimod.reference.composites.clipcomposite.ClipComposite.sample_Ising

ClipComposite.sample_ising(h, J, **parameters)

Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters

- **h** (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form \{v: bias, . . . \} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- **J** (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
- ****kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:

sample(), sample_qubo()

dimod.reference.composites.clipcomposite.ClipComposite.sample_Qubo

ClipComposite.sample_qubo(Q, **parameters)

Sample from a QUBO using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

- **Q** (dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \{(u, v): bias, . . . \} where u, v, are binary-valued variables and bias is their associated coefficient.
- ****kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet
Fixed Variable Composite

A composite that fixes the variables provided and removes them from the binary quadratic model before sending to its child sampler.

Class

class FixedVariableComposite(child_sampler)

Composite to fix variables of a problem to provided.

Fixes variables of a bqm and modifies linear and quadratic terms accordingly. Returned samples include the fixed variable

Parameters

sampler(dimod.Sampler) – A dimod sampler

Examples

This example uses FixedVariableComposite to instantiate a composed sampler that submits a simple Ising problem to a sampler. The composed sampler fixes a variable and modifies linear and quadratic biases according.

```python
>>> h = {1: -1.3, 4: -0.5}
>>> J = {(1, 4): -0.6}
>>> sampler = dimod.FixedVariableComposite(dimod.ExactSolver())
>>> sampleset = sampler.sample_ising(h, J, fixed_variables={1: -1})
```

Properties

<table>
<thead>
<tr>
<th>FixedVariableComposite.child</th>
<th>The child sampler.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FixedVariableComposite.children</td>
<td>List of child samplers that that are used by this composite.</td>
</tr>
<tr>
<td>FixedVariableComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.</td>
</tr>
<tr>
<td>FixedVariableComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

FixedVariableComposite.child

The child sampler. First sampler in Composite.children.

Type: Sampler
dimod.reference.composites.fixedvariable.FixedVariableComposite.children

FixedVariableComposite.children
List of child samplers that are used by this composite.

Type list[Sampler]

dimod.reference.composites.fixedvariable.FixedVariableComposite.parameters

FixedVariableComposite.parameters
A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

Type dict

dimod.reference.composites.fixedvariable.FixedVariableComposite.properties

FixedVariableComposite.properties
A dict containing any additional information about the sampler.

Type dict

Methods

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<th>Method</th>
<th>Description</th>
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<tr>
<td>FixedVariableComposite.sample(bqm)</td>
<td>Sample from the provided binary quadratic model.</td>
</tr>
<tr>
<td>FixedVariableComposite.sample_ising(h, J)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>FixedVariableComposite.sample_qubo(Q)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>

dimod.reference.composites.fixedvariable.FixedVariableComposite.sample

FixedVariableComposite.sample(bqm, fixed_variables=None, **parameters)
Sample from the provided binary quadratic model.

Parameters

- **bqm**(dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from.
- **fixed_variables**(dict) – A dictionary of variable assignments.
- **parameters** – Parameters for the sampling method, specified by the child sampler.

Returns dimod.SampleSet

dimod.reference.composites.fixedvariable.FixedVariableComposite.sample_ising

FixedVariableComposite.sample_ising(h, J, **parameters)
Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().
Parameters

- **h** (*dict/list*) – Linear biases of the Ising problem. If a dict, should be of the form `{v: bias, ...}` where v is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.


- ****kw**args** – See the implemented sampling for additional keyword definitions.

Returns **SampleSet**

See also: `sample()`, `sample_qubo()`

dimod.reference.composites.fixedvariable.FixedVariableComposite.sample_qubo

FixedVariableComposite.sample_qubo(Q, **parameters)

Sample from a QUBO using the implemented sample method.

This method is inherited from the **Sampler** base class.

Converts the QUBO into a **BinaryQuadraticModel** and then calls `sample()`.

Parameters

- **Q** (*dict*) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form `{(u, v): bias, ...}` where u, v, are binary-valued variables and bias is their associated coefficient.

- ****kw**args** – See the implemented sampling for additional keyword definitions.

Returns **SampleSet**

See also: `sample()`, `sample_ising()`

**Roof Duality Composite**

A composite that uses the roof duality algorithm\(^2\) to fix some variables in the binary quadratic model before passing it on to its child sampler.

**Class**

class RoofDualityComposite(child_sampler)

Uses roof duality to assign some variables before invoking child sampler.

Uses the `fix_variables()` function to determine variable assignments, then fixes them before calling the child sampler. Returned samples include the fixed variables.

Parameters

- **child** (*dimod.Sampler*) – A dimod sampler. Used to sample the bqm after variables have been fixed.

---

Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoofDualityComposite.child</td>
<td>The child sampler.</td>
</tr>
<tr>
<td>RoofDualityComposite.children</td>
<td>List of child samplers that are used by this composite.</td>
</tr>
<tr>
<td>RoofDualityComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>RoofDualityComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>RoofDualityComposite.sample(bqm[, sampling_mode])</td>
<td>Sample from the provided binary quadratic model.</td>
</tr>
<tr>
<td>RoofDualityComposite.sample_ising(h, J, ...)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>RoofDualityComposite.sample_qubo(Q, **parameters)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
dimod reference.composites.roofduality.RoofDualityComposite.sample

RoofDualityComposite.sample\((bqm, \text{sampling\_mode}=True, **parameters)\)

Sample from the provided binary quadratic model.

Uses the fix_variables() function to determine which variables to fix.

Parameters

- **bqm** (dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from.
- **sampling\_mode** (bool, optional, default=True) – In sampling mode, only roof-duality is used. When sampling_mode is false, strongly connected components are used to fix more variables, but in some optimal solutions these variables may take different values.
- **parameters** – Parameters for the child sampler.

Returns dimod.SampleSet

dimod.reference.composites.roofduality.RoofDualityComposite.sample_ising

RoofDualityComposite.sample_ising\((h, J, **parameters)\)

Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters

- **h** (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form \(\{v: bias, \ldots\}\) where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- **J** (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
- **kwargs** – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also: sample(), sample_qubo()

dimod.reference.composites.roofduality.RoofDualityComposite.sample_qubo

RoofDualityComposite.sample_qubo\((Q, **parameters)\)

Sample from a QUBO using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

- **Q** (dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \(\{(u, v): bias, \ldots\}\) where \(u, v\) are binary-valued variables and bias is their associated coefficient.
- **kwargs** – See the implemented sampling for additional keyword definitions.
Returns `SampleSet`

See also:

`sample()`, `sample_ising()`

Scale Composite

A composite that scales problem variables as directed. If scalar is not given calculates it based on quadratic and bias ranges.

Class

class ScaleComposite(child_sampler)

Composite to scale variables of a problem

Scales the variables of a bqm and modifies linear and quadratic terms accordingly.

Parameters

- `sampler` *(dimod.Sampler)*: A dimod sampler

Examples

This example uses `ScaleComposite` to instantiate a composed sampler that submits a simple Ising problem to a sampler. The composed sampler scales linear, quadratic biases and offset as indicated by options.

```python
>>> h = {'a': -4.0, 'b': -4.0}
>>> J = {('a', 'b'): 3.2}
>>> sampler = dimod.ScaleComposite(dimod.ExactSolver())
>>> response = sampler.sample_ising(h, J, scalar=0.5,
... ignored_interactions=[('a','b')])
```

Properties

- `ScaleComposite.child` *(Sampler)*: The child sampler.
- `ScaleComposite.children` *(List)*: List of child samplers that that are used by this composite.
- `ScaleComposite.parameters` *(dict)*: A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.
- `ScaleComposite.properties` *(dict)*: A dict containing any additional information about the sampler.

`dimod.reference.composites.scalecomposite.ScaleComposite.child`

`ScaleComposite.child`  
The child sampler. First sampler in `Composite.children`.  
Type `Sampler`
ScaleComposite.

**children**

List of child samplers that are used by this composite.

**Type** list[Sampler]

ScaleComposite.

**parameters**

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

**Type** dict

ScaleComposite.

**properties**

A dict containing any additional information about the sampler.

**Type** dict

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>
| ScaleComposite.

**sample**(bqm[, scalar,...]) | Scale and sample from the provided binary quadratic model. |
| ScaleComposite.

**sample_ising**(h, J[, offset,...]) | Scale and sample from the problem provided by h, J, offset |
| ScaleComposite.

**sample_qubo**(Q, **parameters)** | Sample from a QUBO using the implemented sample method. |

ScaleComposite.

**sample**(bqm, scalar=None, bias_range=1, quadratic_range=None, ignored_variables=None, ignored_interactions=None, ignore_offset=False, **parameters)**

Scale and sample from the provided binary quadratic model.

if scalar is not given, problem is scaled based on bias and quadratic ranges. See BinaryQuadraticModel.

scale() and BinaryQuadraticModel.normalize()
• **`ignored_variables`** *(iterable, optional)* – Biases associated with these variables are not scaled.

• **`ignored_interactions`** *(iterable[tuple], optional)* – As an iterable of 2-tuples. Biases associated with these interactions are not scaled.

• **`ignore_offset`** *(bool, default=False)* – If True, the offset is not scaled.

• **`**parameters**` – Parameters for the sampling method, specified by the child sampler.

Returns *`dimod.SampleSet`*

**dimod.reference.composites.scalecomposite.ScaleComposite.sample_ising**

`ScaleComposite.sample_ising(h, J, offset=0, scalar=None, bias_range=1, quadratic_range=None, ignored_variables=None, ignored_interactions=None, ignore_offset=False, **parameters)`

Scale and sample from the problem provided by h, J, offset if scalar is not given, problem is scaled based on bias and quadratic ranges.

Parameters

• **`h (dict)`** – linear biases

• **`J (dict)`** – quadratic or higher order biases

• **`offset (float, optional)`** – constant energy offset

• **`scalar (number)`** – Value by which to scale the energy range of the binary quadratic model.

• **`bias_range (number/pair)`** – Value/range by which to normalize the all the biases, or if `quadratic_range` is provided, just the linear biases.

• **`quadratic_range (number/pair)`** – Value/range by which to normalize the quadratic biases.

• **`ignored_variables (iterable, optional)`** – Biases associated with these variables are not scaled.

• **`ignored_interactions (iterable[tuple], optional)`** – As an iterable of 2-tuples. Biases associated with these interactions are not scaled.

• **`ignore_offset (bool, default=False)`** – If True, the offset is not scaled.

• **`**parameters**` – Parameters for the sampling method, specified by the child sampler.

Returns *`dimod.SampleSet`*

**dimod.reference.composites.scalecomposite.ScaleComposite.sample_qubo**

`ScaleComposite.sample_qubo(Q, **parameters)`

Sample from a QUBO using the implemented sample method.

This method is inherited from the `Sampler` base class.

Converts the QUBO into a `BinaryQuadraticModel` and then calls `sample()`.

Parameters
• \(Q(dict)\) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \(\{(u, v): bias, \ldots\}\) where \(u, v\) are binary-valued variables and bias is their associated coefficient.

• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also: sample(), sample_ising()

Spin Reversal Transform Composite

On the D-Wave system, coupling \(J_{i,j}\) adds a small bias to qubits \(i\) and \(j\) due to leakage. This can become significant for chained qubits. Additionally, qubits are biased to some small degree in one direction or another. Applying a spin-reversal transform can improve results by reducing the impact of possible analog and systematic errors. A spin-reversal transform does not alter the Ising problem; the transform simply amounts to reinterpreting spin up as spin down, and visa-versa, for a particular spin.

Class

class SpinReversalTransformComposite(child)

Composite for applying spin reversal transform preprocessing.

Spin reversal transforms (or “gauge transformations”) are applied by flipping the spin of variables in the Ising problem. After sampling the transformed Ising problem, the same bits are flipped in the resulting sample\(^3\).

Parameters sampler – A dimod sampler object.

Examples

This example composes a dimod ExactSolver sampler with spin transforms then uses it to sample an Ising problem.

```python
>>> # Compose the sampler
>>> base_sampler = dimod.ExactSolver()
>>> composed_sampler = dimod.SpinReversalTransformComposite(base_sampler)
>>> base_sampler in composed_sampler.children
True
>>> # Sample an Ising problem
>>> response = composed_sampler.sample_ising({'a': -0.5, 'b': 1.0}, {('a', 'b'): -1})
>>> print(next(response.data()))  # doctest: +SKIP
Sample(sample={'a': 1, 'b': 1}, energy=-1.5)
```

References

Properties

---

SpinReversalTransformComposite.child

The child sampler.

SpinReversalTransformComposite.children

SpinReversalTransformComposite.parameters

SpinReversalTransformComposite.properties

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.child

SpinReversalTransformComposite.child

The child sampler. First sampler in Composite.children.

Type: Sampler

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.children

SpinReversalTransformComposite.children = None

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.parameters

SpinReversalTransformComposite.parameters = None

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.properties

SpinReversalTransformComposite.properties = None

Methods

SpinReversalTransformComposite.sample(bqm[, ...])

Sample from the binary quadratic model.

SpinReversalTransformComposite.sample_ising(h,...)

Sample from an Ising model using the implemented sample method.

SpinReversalTransformComposite.sample_qubo(Q,...)

Sample from a QUBO using the implemented sample method.

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.sample

SpinReversalTransformComposite.sample(bqm, num_spin_reversal_transforms=2, spin_reversal_variables=None, **kwargs)

Sample from the binary quadratic model.

Parameters

- **bqm** (*BinaryQuadraticModel*) – Binary quadratic model to be sampled from.
- **num_spin_reversal_transforms** (*integer, optional, default=2*) – Number of spin reversal transform runs.
• **spin_reversal_variables** *(list/dict, optional)* – Deprecated and no longer functional.

Returns *SampleSet*

**Examples**

This example runs 100 spin reversals applied to one variable of a QUBO problem.

```python
>>> import dimod
... >>> base_sampler = dimod.ExactSolver()
... >>> composed_sampler = dimod.SpinReversalTransformComposite(base_sampler)
... >>> Q = {('a', 'a'): -1, ('b', 'b'): -1, ('a', 'b'): 2}
... >>> response = composed_sampler.sample_qubo(Q,
...                                          num_spin_reversal_transforms=100,
...                                          spin_reversal_variables={'a'})
... >>> len(response)
400
... >>> print(next(response.data()))  # doctest: +SKIP
Sample(sample={'a': 0, 'b': 1}, energy=-1.0)
```

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.sample_ising

**SpinReversalTransformComposite.sample_ising**(h, J, **parameters)**

Sample from an Ising model using the implemented sample method.

This method is inherited from the *Sampler* base class.

Converts the Ising model into a *BinaryQuadraticModel* and then calls *sample()*.

**Parameters**

- **h** *(dict/list)* – Linear biases of the Ising problem. If a dict, should be of the form `{v: bias, ...}` where is a spin-valued variable and *bias* is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.

- **J** *(dict[(variable, variable), bias])* – Quadratic biases of the Ising problem.

- ****kwargs – See the implemented sampling for additional keyword definitions.

Returns *SampleSet*

See also:

*sample(), sample_qubo()*

dimod.reference.composites.spin_transform.SpinReversalTransformComposite.sample_qubo

**SpinReversalTransformComposite.sample_qubo**(Q, **parameters)**

Sample from a QUBO using the implemented sample method.

This method is inherited from the *Sampler* base class.

Converts the QUBO into a *BinaryQuadraticModel* and then calls *sample()*.

**Parameters**
• **Q**\(\text{(dict)}\) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \(\{(u, v): \text{bias}, \ldots\}\) where \(u, v\) are binary-valued variables and \(\text{bias}\) is their associated coefficient.

• ****kwargs – See the implemented sampling for additional keyword definitions.

Returns `SampleSet`

See also: `sample()`, `sample_ising()`

Structured Composite

A composite that structures a sampler.

Class

class StructureComposite *(sampler, nodelist, edgelist)*

Creates a structured composed sampler from an unstructured sampler.

Parameters

• `Sampler(Sampler)` – Unstructured sampler.

• `nodelist(list)` – Nodes/variables allowed by the sampler formatted as a list.

• `edgelist(list[(node, node)])` – Edges/interactions allowed by the sampler, formatted as a list where each edge/interaction is a 2-tuple.

Examples

This example creates a composed sampler from the unstructured dimod ExactSolver sampler. The target structure is a square graph.

```python
>>> import dimod
...  
>>> base_sampler = dimod.ExactSolver()
>>> node_list = [0, 1, 2, 3]
>>> edge_list = [(0, 1), (1, 2), (2, 3), (0, 3)]
>>> structured_sampler = dimod.StructureComposite(base_sampler, node_list, edge_list)
>>> linear = {0: 0.0, 1: 0.0, 2: 0.0, 3: 0.0}
>>> quadratic = {(0, 1): 1.0, (1, 2): 1.0, (0, 3): 1.0, (2, 3): -1.0}
>>> bqm = dimod.BinaryQuadraticModel(linear, quadratic, 1.0, dimod.Vartype.SPIN)
>>> response = structured_sampler.sample(bqm)
>>> print(next(response.data()))
Sample(sample={0: 1, 1: -1, 2: -1, 3: -1}, energy=-1.0, num_occurrences=1)
>>> # Try giving the composed sampler a non-square model
>>> del quadratic[(0, 1)]
>>> quadratic[(0, 2)] = 1.0
>>> bqm = dimod.BinaryQuadraticModel(linear, quadratic, 1.0, dimod.Vartype.SPIN)
>>> try: response = structured_sampler.sample(bqm)  # doctest: +SKIP
... except dimod.BinaryQuadraticModelStructureError as details:
...     print(details)
... given bqm does not match the sampler's structure
```
Properties

<table>
<thead>
<tr>
<th>StructureComposite.child</th>
<th>The child sampler.</th>
</tr>
</thead>
<tbody>
<tr>
<td>StructureComposite.children</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>StructureComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

dimod.reference.composites.structure.StructureComposite.child

StructureComposite.child

The child sampler. First sampler in Composite.children.

Type Sampler

dimod.reference.composites.structure.StructureComposite.children

StructureComposite.children = None

dimod.reference.composites.structure.StructureComposite.parameters

StructureComposite.parameters

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

Type dict

dimod.reference.composites.structure.StructureComposite.properties

StructureComposite.properties

A dict containing any additional information about the sampler.

Type dict

Methods

<table>
<thead>
<tr>
<th>StructureComposite.sample(bqm, **sample_kwargs)</th>
<th>Sample from the binary quadratic model.</th>
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</thead>
<tbody>
<tr>
<td>StructureComposite.sample_ising(h, J, ...)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>StructureComposite.sample_qubo(Q, **parameters)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
dimod.reference.composites.structure.StructureComposite.sample

StructureComposite.sample(bqm, **sample_kwargs)
Sample from the binary quadratic model.

Parameters

- bqm (BinaryQuadraticModel) – Binary quadratic model to be sampled from.

Returns

SampleSet

Examples

This example submits an Ising problem to a composed sampler that uses the dimod ExactSolver only on problems structured for a K2 fully connected graph.

```python
>>> import dimod
... >>> response = dimod.StructureComposite(dimod.ExactSolver(),
... [0, 1], [(0, 1)]).sample_ising({0: 1, 1: 1}, {})
... >>> print(next(response.data()))
Sample(sample={0: -1, 1: -1}, energy=-2.0, num_occurrences=1)
```

dimod.reference.composites.structure.StructureComposite.sample_ising

StructureComposite.sample_ising(h, J, **parameters)
Sample from an Ising model using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters

- h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form {v: bias, ...} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
- J (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
- **kwargs – See the implemented sampling for additional keyword definitions.

Returns

SampleSet

See also:

sample(), sample_qubo()

dimod.reference.composites.structure.StructureComposite.sample_qubo

StructureComposite.sample_qubo(Q, **parameters)
Sample from a QUBO using the implemented sample method.
This method is inherited from the Sampler base class.
Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters
• $Q(dict)$ – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form ${(u, v): \text{bias}, \ldots}$ where $u, v$ are binary-valued variables and \text{bias} is their associated coefficient.

• **kwargs – See the implemented sampling for additional keyword definitions.

Returns \text{SampleSet}

See also: \text{sample()}, \text{sample_ising()}

Tracking Composite

A composite that tracks inputs and outputs.

Class

class TrackingComposite(child=\text{dimod.Sampler}, copy=False)

Composite that tracks inputs and outputs for debugging and testing.

Parameters

• \text{child}(\text{dimod.Sampler}) – A dimod sampler.

• \text{copy}(\text{bool}, \text{optional}, \text{default=False}) – If True, the inputs/outputs are copied (with \text{copy.deepcopy()}) before they are stored. This is useful if the child sampler mutates the values.

Examples

```python
>>> sampler = dimod.TrackingComposite(dimod.RandomSampler())
>>> sampleset = sampler.sample_ising({'a': -1}, {('a', 'b'): 1},
... num_reads=5)
>>> sampler.input
OrderedDict([('h', {'a': -1}), ('J', {('a', 'b'): 1}), ('num_reads', 5)])
>>> sampleset == sampler.output
True
```

If we make additional calls to the sampler, the most recent input/output are stored in \text{input} and \text{output} respectively. However, all are tracked in \text{inputs} and \text{outputs}.

```python
>>> sampleset = sampler.sample_qubo({('a', 'b'): 1})
>>> sampler.input
OrderedDict([('Q', {('a', 'b'): 1})])
>>> sampler.inputs  # doctest: +SKIP
[OrderedDict([('h', {'a': -1}), ('J', {('a', 'b'): 1}), ('num_reads', 5))],
 OrderedDict([('Q', {('a', 'b'): 1})])]
```

In the case that you want to nest the tracking composite, there are two patterns for retrieving the data

```python
>>> from dimod import ScaleComposite, TrackingComposite, ExactSolver
... >>> sampler = ScaleComposite(TrackingComposite(ExactSolver()))
... >>> sampler.child.inputs  # empty because we haven't called sample
[]
```
>>> intermediate_sampler = TrackingComposite(ExactSolver())
>>> sampler = ScaleComposite(intermediate_sampler)
>>> intermediate_sampler.inputs
[]

Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TrackingComposite.input</td>
<td>The most recent input to any sampling method.</td>
</tr>
<tr>
<td>TrackingComposite.inputs</td>
<td>All of the inputs to any sampling methods.</td>
</tr>
<tr>
<td>TrackingComposite.output</td>
<td>The most recent output of any sampling method.</td>
</tr>
<tr>
<td>TrackingComposite.outputs</td>
<td>All of the outputs from any sampling methods.</td>
</tr>
<tr>
<td>TrackingComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.</td>
</tr>
<tr>
<td>TrackingComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

**dimod.reference.composites.tracking.TrackingComposite.input**

TrackingComposite.**input**
The most recent input to any sampling method.

**dimod.reference.composites.tracking.TrackingComposite.inputs**

TrackingComposite.**inputs**
All of the inputs to any sampling methods.

**dimod.reference.composites.tracking.TrackingComposite.output**

TrackingComposite.**output**
The most recent output of any sampling method.

**dimod.reference.composites.tracking.TrackingComposite.outputs**

TrackingComposite.**outputs**
All of the outputs from any sampling methods.

**dimod.reference.composites.tracking.TrackingComposite.parameters**

TrackingComposite.**parameters**
A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.

  **Type**  dict
dimod.reference.composites.tracking.TrackingComposite.properties

**TrackingComposite.properties**  
A dict containing any additional information about the sampler.  

*Type*  
dict

**Methods**

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<td>Clear all the inputs/outputs.</td>
<td></td>
</tr>
<tr>
<td>TrackingComposite.sample(bqm, **parameters)</td>
<td>Sample from the child sampler and store the given inputs/outputs.</td>
<td>bqm (dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from. **kwargs – Parameters for the sampling method, specified by the child sampler.</td>
</tr>
<tr>
<td>TrackingComposite.sample_ising(h, J, **parameters)</td>
<td>Sample from the child sampler and store the given inputs/outputs.</td>
<td>h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form {v: bias, ...} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels. J (dict[variable, variable], bias) – Quadratic biases of the Ising problem. **kwargs – Parameters for the sampling method, specified by the child sampler.</td>
</tr>
</tbody>
</table>

**dimod.reference.composites.tracking.TrackingComposite.clear**

TrackingComposite.clear()  
Clear all the inputs/outputs.

**dimod.reference.composites.tracking.TrackingComposite.sample**

TrackingComposite.sample(bqm, **parameters)  
Sample from the child sampler and store the given inputs/outputs.  
The binary quadratic model and any parameters are stored in inputs. The returned sample set is stored in outputs.  

*Parameters*  
• bqm (dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from.  
• **kwargs – Parameters for the sampling method, specified by the child sampler.  

*Returns*  
dimod.SampleSet

**dimod.reference.composites.tracking.TrackingComposite.sample_ising**

TrackingComposite.sample_ising(h, J, **parameters)  
Sample from the child sampler and store the given inputs/outputs.  
The binary quadratic model and any parameters are stored in inputs. The returned sample set is stored in outputs.  

*Parameters*  
• h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form {v: bias, ...} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.  
• J (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem. **kwargs – Parameters for the sampling method, specified by the child sampler.  

*Returns*  
dimod.SampleSet
**kwargs – Parameters for the sampling method, specified by the child sampler.

**Returns**: dimod.SampleSet

**dimod.reference.composites.tracking.TrackingComposite.sample_qubo**

`TrackingComposite.sample_qubo(Q, **parameters)`

Sample from the child sampler and store the given inputs/outputs.

The binary quadratic model and any parameters are stored in `inputs`. The returned sample set is stored in `outputs`.

**Parameters**

- `Q (dict)` – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form `{(u, v): bias, ...}` where `u`, `v`, are binary-valued variables and `bias` is their associated coefficient.
- **kwargs – Parameters for the sampling method, specified by the child sampler.

**Returns**: dimod.SampleSet

**Truncate Composite**

A composite that truncates the response based on options provided by the user.

**Class**

```python
class TruncateComposite(child_sampler, n, sorted_by='energy', aggregate=False)
```

Composite to truncate the returned samples

Inherits from `dimod.ComposedSampler`.

Post-processing is expensive and sometimes one might want to only treat the lowest energy samples. This composite layer allows one to pre-select the samples within a multi-composite pipeline.

**Parameters**

- `child_sampler (dimod.Sampler)` – A dimod sampler
- `n (int)` – Maximum number of rows in the returned sample set.
- `sorted_by (str/None, optional, default='energy')` – Selects the record field used to sort the samples before truncating. Note that sample order is maintained in the underlying array.
- `aggregate (bool, optional, default=False)` – If True, aggregate the samples before truncating.

**Note**: If aggregate is True `SampleSet.record.num_occurrences` are accumulated but no other fields are.

**Properties**
### dimod.Documentation, Release 0.8.21

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
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<td><code>TruncateComposite.children</code></td>
<td>List of child samplers that that are used by this composite.</td>
</tr>
<tr>
<td><code>TruncateComposite.parameters</code></td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.</td>
</tr>
<tr>
<td><code>TruncateComposite.properties</code></td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

#### dimod.reference.composites.truncatecomposite.TruncateComposite.child

**TruncateComposite.child**

The child sampler. First sampler in Composite.children.

**Type** Sampler

#### dimod.reference.composites.truncatecomposite.TruncateComposite.children

**TruncateComposite.children**

List of child samplers that that are used by this composite.

**Type** list[Sampler]

#### dimod.reference.composites.truncatecomposite.TruncateComposite.parameters

**TruncateComposite.parameters**

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.

**Type** dict

#### dimod.reference.composites.truncatecomposite.TruncateComposite.properties

**TruncateComposite.properties**

A dict containing any additional information about the sampler.

**Type** dict

### Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><code>TruncateComposite.sample(bqm,**kwargs)</code></td>
<td>Sample from the problem provided by bqm and truncate output.</td>
</tr>
<tr>
<td><code>TruncateComposite.sample_ising(h,J,...)</code></td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td><code>TruncateComposite.sample_qubo(Q,**parameters)</code></td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>
dimod.reference.composites.truncatecomposite.TruncateComposite.sample

TruncateComposite.sample(bqm, **kwargs)
Sample from the problem provided by bqm and truncate output.

Parameters

• bqm(dimod.BinaryQuadraticModel) – Binary quadratic model to be sampled from.
• **kwargs – Parameters for the sampling method, specified by the child sampler.

Returns dimod.SampleSet

dimod.reference.composites.truncatecomposite.TruncateComposite.sample_ising

TruncateComposite.sample_ising(h, J, **parameters)
Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().

Parameters

• h (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form {v: bias, ...} where is a spin-valued variable and bias is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.
• J (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.
• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:

sample(), sample_qubo()

dimod.reference.composites.truncatecomposite.TruncateComposite.sample_qubo

TruncateComposite.sample_qubo(Q, **parameters)
Sample from a QUBO using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

• Q(dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form {(u, v): bias, ...} where u, v, are binary-valued variables and bias is their associated coefficient.
• **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:

sample(), sample_ising()
Higher-Order Composites

The dimod package includes several example higher-order composed samplers.

HigherOrderComposite

class HigherOrderComposite(child_sampler)

Convert a binary quadratic model sampler to a binary polynomial sampler.

Energies of the returned samples do not include the penalties.

Parameters

- sampler (dimod.Sampler) — A dimod sampler

Example

This example uses HigherOrderComposite to instantiate a composed sampler that submits a simple Ising problem to a sampler. The composed sampler creates a bqm from a higher order problem.

```python
>>> sampler = dimod.HigherOrderComposite(dimod.ExactSolver())
>>> h = {0: -0.5, 1: -0.3, 2: -0.8}
>>> J = {(0, 1, 2): -1.7}
>>> sampleset = sampler.sample_hising(h, J, discard_unsatisfied=True)
>>> sampleset.first
# doctest: +SKIP
Sample(sample={0: 1, 1: 1, 2: 1},
  energy=-3.3,
  num_occurrences=1,
  penalty_satisfaction=True)
```

Properties

| HigherOrderComposite.child | The child sampler. |
| HigherOrderComposite.children | A list containing the wrapped sampler. |
| HigherOrderComposite.parameters | A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter. |
| HigherOrderComposite.properties | A dict containing any additional information about the sampler. |

dimod.reference.composites.HigherOrderComposite.child

HigherOrderComposite.child

The child sampler. First sampler in Composite.children.

Type Sampler

dimod.reference.composites.HigherOrderComposite.children

HigherOrderComposite.children

A list containing the wrapped sampler.
**dimod.reference.composites.HigherOrderComposite.parameters**

**HigherOrderComposite.parameters**  
A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.  

**Type** dict  

**dimod.reference.composites.HigherOrderComposite.properties**

**HigherOrderComposite.properties**  
A dict containing any additional information about the sampler.  

**Type** dict  

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>
| `HigherOrderComposite.sample_poly(poly[, penalty_strength=1.0, keep_penalty_variables=False, discard_unsatisfied=False, **parameters])` | Sample from the given binary polynomial. Takes the given binary polynomial, introduces penalties, reduces the higher-order problem into a quadratic problem and sends it to its child sampler.  

**Parameters**

- **poly** *(BinaryPolynomial)* – A binary polynomial.  
- **penalty_strength** *(float, optional)* – Strength of the reduction constraint. Insufficient strength can result in the binary quadratic model not having the same minimization as the polynomial.  
- **keep_penalty_variables** *(bool, optional)* – default is True. If False will remove the variables used for penalty from the samples  
- **discard_unsatisfied** *(bool, optional)* – default is False. If True will discard samples that do not satisfy the penalty conditions.  
- **initial_state** *(dict, optional)* – Only accepted when the child sampler accepts an initial state. The initial state is given in terms of the variables in the binary polynomial. The corresponding initial values are populated for use by the child sampler.  
- ****parameters – Parameters for the sampling method, specified by  

**Returns** `dimod.SampleSet`
dimod Documentation, Release 0.8.21

**dimod.reference.composites.HigherOrderComposite.sample_hising**

HigherOrderComposite.sample_hising(h, J, **kwargs)

Sample from a higher-order Ising model.

Convert the given higher-order Ising model to a `BinaryPolynomial` and call `sample_poly()`.

Parameters

- **h** (dict) – Variable biases of the Ising problem as a dict of the form `{v: bias, ...}`, where `v` is a variable in the polynomial and `bias` its associated coefficient.
- **J** (dict) – Interaction biases of the Ising problem as a dict of the form `{(u, v, ...): bias}`, where `u, v`, are spin-valued variables in the polynomial and `bias` their associated coefficient.
- **kwarg** – See `sample_poly()` for additional keyword definitions.

Returns SampleSet

See also:

`sample_poly()`, `sample_hubo()`

**dimod.reference.composites.HigherOrderComposite.sample_hubo**

HigherOrderComposite.sample_hubo(H, **kwargs)

Sample from a higher-order unconstrained binary optimization problem.

Convert the given higher-order unconstrained binary optimization problem to a `BinaryPolynomial` and then call `sample_poly()`.

Parameters

- **H** (dict) – Coefficients of the HUBO as a dict of the form `{(u, v, ...): bias, ...}`, where `u, v`, are binary-valued variables in the polynomial and `bias` their associated coefficient.
- **kwarg** – See `sample_poly()` for additional keyword definitions.

Returns SampleSet

See also:

`sample_poly()`, `sample_hising()`

**PolyFixedVariableComposite**

class PolyFixedVariableComposite(child_sampler)

Composite to fix variables of a problem to provided.

Fixes variables of a binary polynomial and modifies linear and k-local terms accordingly. Returned samples include the fixed variable

Parameters **sampler** (dimod.PolySampler) – A dimod polynomial sampler.

**Examples**

This example uses `PolyFixedVariableComposite` to instantiate a composed sampler that submits a simple high order Ising problem to a sampler. The composed sampler fixes a variable and modifies linear and k-local terms biases according.
```python
>>> h = {1: -1.3, 2: 1.2, 3: -3.4, 4: -0.5}
>>> J = {(1, 4): -0.6, (1, 2, 3): 0.2, (1, 2, 3, 4): -0.1}
>>> poly = dimod.BinaryPolynomial.from_hising(h, J, offset=0)
>>> sampler = dimod.PolyFixedVariableComposite(dimod.ExactPolySolver())
>>> sampleset = sampler.sample_poly(poly, fixed_variables={3: -1, 4: 1})
```

Properties

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>PolyFixedVariableComposite.child</td>
<td>The child sampler.</td>
</tr>
<tr>
<td>PolyFixedVariableComposite.children</td>
<td>List of child samplers that that are used by this composite.</td>
</tr>
<tr>
<td>PolyFixedVariableComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>PolyFixedVariableComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
</tr>
</tbody>
</table>

```python
dimod.reference.composites.PolyFixedVariableComposite.child

PolyFixedVariableComposite.child

The child sampler. First sampler in Composite.children.

  Type  Sampler
```

```python
dimod.reference.composites.PolyFixedVariableComposite.children

PolyFixedVariableComposite.children

List of child samplers that that are used by this composite.

  Type  list[ Sampler]
```

```python
dimod.reference.composites.PolyFixedVariableComposite.parameters

PolyFixedVariableComposite.parameters

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

  Type  dict
```

```python
dimod.reference.composites.PolyFixedVariableComposite.properties

PolyFixedVariableComposite.properties

A dict containing any additional information about the sampler.

  Type  dict
```

Methods
PolyFixedVariableComposite.sample_poly(poly)  Sample from the provided binary quadratic model.

PolyFixedVariableComposite.sample_hising(h, ...)  Sample from a higher-order Ising model.

PolyFixedVariableComposite.sample_hubo(H, ...)  Sample from a higher-order unconstrained binary optimization problem.

dimod.reference.composites.PolyFixedVariableComposite.sample_poly

PolyFixedVariableComposite.sample_poly(poly, fixed_variables=None, **parameters)
Sample from the provided binary quadratic model.

Parameters
- poly (dimod.BinaryPolynomial) – Binary polynomial model to be sampled from.
- fixed_variables (dict) – A dictionary of variable assignments.
- **parameters – Parameters for the sampling method, specified by the child sampler.

Returns dimod.SampleSet

dimod.reference.composites.PolyFixedVariableComposite.sample_hising

PolyFixedVariableComposite.sample_hising(h, J, **kwargs)
Sample from a higher-order Ising model.
Convert the given higher-order Ising model to a BinaryPolynomial and call sample_poly().

Parameters
- h (dict) – Variable biases of the Ising problem as a dict of the form {v: bias, ...}, where v is a variable in the polynomial and bias its associated coefficient.
- J (dict) – Interaction biases of the Ising problem as a dict of the form {(u, v, ...): bias}, where u, v, are spin-valued variables in the polynomial and bias their associated coefficient.
- **kwargs – See sample_poly() for additional keyword definitions.

Returns SampleSet

See also:
sample_poly(), sample_hubo()

dimod.reference.composites.PolyFixedVariableComposite.sample_hubo

PolyFixedVariableComposite.sample_hubo(H, **kwargs)
Sample from a higher-order unconstrained binary optimization problem.
Convert the given higher-order unconstrained binary optimization problem to a BinaryPolynomial and then call sample_poly().

Parameters
- H (dict) – Coefficients of the HUBO as a dict of the form {(u, v, ...): bias, ...}, where u, v, are binary-valued variables in the polynomial and bias their associated coefficient.
- **kwargs – See sample_poly() for additional keyword definitions.
Returns `SampleSet`

See also:

`sample_poly()`, `sample_hising()`

**PolyScaleComposite**

class PolyScaleComposite(child)

Composite to scale biases of a binary polynomial.

**Parameters**

`child` *(PolySampler)* – A binary polynomial sampler.

**Examples**

```python
>>> linear = {'a': -4.0, 'b': -4.0}
>>> quadratic = {('a', 'b'): 3.2, ('a', 'b', 'c'): 1}
>>> sampler = dimod.PolyScaleComposite(dimod.HigherOrderComposite(dimod.ExactSolver()))
>>> response = sampler.sample_hising(linear, quadratic, scalar=0.5, ... ignored_terms=[('a','b')])
```

**Properties**

<table>
<thead>
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<th>Property</th>
<th>Description</th>
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<tbody>
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<td>The child sampler.</td>
</tr>
<tr>
<td>PolyScaleComposite.children</td>
<td>The child sampler in a list</td>
</tr>
<tr>
<td>PolyScaleComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>PolyScaleComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
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</table>

`dimod.reference.composites.PolyScaleComposite.child`

**PolyScaleComposite.child**

The child sampler. First sampler in Composite.children.

**Type** `Sampler`

`dimod.reference.composites.PolyScaleComposite.children`

**PolyScaleComposite.children**

The child sampler in a list

`dimod.reference.composites.PolyScaleComposite.parameters`

**PolyScaleComposite.parameters**

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.
**Type**  
dict

**dimod.reference.composites.PolyScaleComposite.properties**

**PolyScaleComposite.properties**  
A dict containing any additional information about the sampler.

**Type**  
dict

**Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>PolyScaleComposite.sample_poly(poly, ...))</td>
<td>Scale and sample from the given binary polynomial.</td>
</tr>
<tr>
<td>PolyScaleComposite.sample_hising(h, J, **kwargs)</td>
<td>Sample from a higher-order Ising model.</td>
</tr>
<tr>
<td>PolyScaleComposite.sample_hubo(H, **kwargs)</td>
<td>Sample from a higher-order unconstrained binary optimization problem.</td>
</tr>
</tbody>
</table>

**dimod.reference.composites.PolyScaleComposite.sample_poly**

**PolyScaleComposite.sample_poly**  
Scale and sample from the given binary polynomial.

If scalar is not given, problem is scaled based on bias and polynomial ranges. See *BinaryPolynomial*. *scale() and BinaryPolynomial.normalize()*

**Parameters**

- **(obj (poly)) – BinaryPolynomial**: A binary polynomial.
- **scalar (number, optional)** – Value by which to scale the energy range of the binary polynomial.
- **bias_range (number/pair, optional, default=1)** – Value/range by which to normalize the all the biases, or if *poly_range* is provided, just the linear biases.
- **poly_range (number/pair, optional)** – Value/range by which to normalize the higher order biases.
- **ignored_terms (iterable, optional)** – Biases associated with these terms are not scaled.
- ****parameters** – Other parameters for the sampling method, specified by the child sampler.

**dimod.reference.composites.PolyScaleComposite.sample_hising**

**PolyScaleComposite.sample_hising**  
Sample from a higher-order Ising model.

Convert the given higher-order Ising model to a *BinaryPolynomial* and call *sample_poly()*.  

**Parameters**
• **kwargs – See `sample_poly()` for additional keyword definitions.

Returns `SampleSet`

See also:

`sample_poly()`, `sample_hubo()`

dimod.reference.composites.PolyScaleComposite.sample_hubo

`PolyScaleComposite.sample_hubo(H, **kwargs)`

Sample from a higher-order unconstrained binary optimization problem.

Convert the given higher-order unconstrained binary optimization problem to a `BinaryPolynomial` and then call `sample_poly()`.

Parameters

• **kwargs – See `sample_poly()` for additional keyword definitions.

Returns `SampleSet`

See also:

`sample_poly()`, `sample_hising()`

PolyTruncateComposite

class `PolyTruncateComposite` (child_sampler, n, sorted_by='energy', aggregate=False)

Composite to truncate the returned samples

Post-processing is expensive and sometimes one might want to only treat the lowest energy samples. This composite layer allows one to pre-select the samples within a multi-composite pipeline.

Parameters

• **kwargs – See `sample_poly()` for additional keyword definitions.

Returns `SampleSet`

See also:

`sample_poly()`, `sample_hising()`

Note: If aggregate is True `SampleSet.record.num_occurrences` are accumulated but no other fields are.
Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PolyTruncateComposite.child</td>
<td>The child sampler.</td>
</tr>
<tr>
<td>PolyTruncateComposite.children</td>
<td>List of child samplers that that are used by this composite.</td>
</tr>
<tr>
<td>PolyTruncateComposite.parameters</td>
<td>A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.</td>
</tr>
<tr>
<td>PolyTruncateComposite.properties</td>
<td>A dict containing any additional information about the sampler.</td>
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</table>

Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PolyTruncateComposite.sample_poly(poly, **kwargs)</td>
<td>Sample from the binary polynomial and truncate output.</td>
</tr>
<tr>
<td>PolyTruncateComposite.sample_hising(h, J,...)</td>
<td>Sample from a higher-order Ising model.</td>
</tr>
<tr>
<td>PolyTruncateComposite.sample_hubo(H, **kwargs)</td>
<td>Sample from a higher-order unconstrained binary optimization problem.</td>
</tr>
</tbody>
</table>
**dimod.reference.composites.PolyTruncateComposite.sample_poly**

`PolyTruncateComposite.sample_poly(poly, **kwargs)`  
Sample from the binary polynomial and truncate output.

**Parameters**
- `(obj (poly) = BinaryPolynomial)`: A binary polynomial.
- `**kwargs` – Parameters for the sampling method, specified by the child sampler.

**Returns** `dimod.SampleSet`

**dimod.reference.composites.PolyTruncateComposite.sample_hising**

`PolyTruncateComposite.sample_hising(h, J, **kwargs)`  
Sample from a higher-order Ising model.

Convert the given higher-order Ising model to a `BinaryPolynomial` and call `sample_poly()`.

**Parameters**
- `h (dict)` – Variable biases of the Ising problem as a dict of the form `{v: bias, ...}`, where `v` is a variable in the polynomial and `bias` its associated coefficient.
- `J (dict)` – Interaction biases of the Ising problem as a dict of the form `{(u, v, ...): bias}`, where `u, v` are spin-valued variables in the polynomial and `bias` their associated coefficient.
- `**kwargs` – See `sample_poly()` for additional keyword definitions.

**Returns** `SampleSet`

**See also:**
- `sample_poly()`, `sample_hubo()`

**dimod.reference.composites.PolyTruncateComposite.sample_hubo**

`PolyTruncateComposite.sample_hubo(H, **kwargs)`  
Sample from a higher-order unconstrained binary optimization problem.

Convert the given higher-order unconstrained binary optimization problem to a `BinaryPolynomial` and then call `sample_poly()`.

**Parameters**
- `H (dict)` – Coefficients of the HUBO as a dict of the form `{(u, v, ...): bias, ...}`, where `u, v` are binary-valued variables in the polynomial and `bias` their associated coefficient.
- `**kwargs` – See `sample_poly()` for additional keyword definitions.

**Returns** `SampleSet`

**See also:**
- `sample_poly()`, `sample_hising()`

**API for Samplers and Composites**

You can create your own samplers with dimod’s `Sampler` abstract base class (ABC) providing complementary methods (e.g., ‘sample_qubo’ if only ‘sample_ising’ is implemented), consistent responses, etc.
Properties of dimod Sampler Abstract Base Classes

The following table describes the inheritance, properties, methods/mixins of sampler ABCs.

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<td>sample(), sample_ising(), sample_qubo()</td>
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<tr>
<td>Structured</td>
<td></td>
<td>nodelist, edgelist</td>
<td></td>
<td>structure, adjacency</td>
</tr>
<tr>
<td>Composite</td>
<td></td>
<td>children</td>
<td></td>
<td>child</td>
</tr>
<tr>
<td>ComposedSampler</td>
<td>Sampler,</td>
<td>parameters, children</td>
<td>at least one of sample(), sample_ising(), sample_qubo()</td>
<td>sample(), sample_ising(), sample_qubo(), child</td>
</tr>
<tr>
<td>PolySampler</td>
<td></td>
<td>parameters, properties</td>
<td>sample_poly()</td>
<td>sample_hising(), sample_hubo()</td>
</tr>
<tr>
<td>ComposedPolySampler</td>
<td>PolySampler, Composite</td>
<td>parameters, children</td>
<td>sample_poly()</td>
<td>sample_hising(), sample_hubo(), child</td>
</tr>
</tbody>
</table>

The table shows, for example, that the Sampler class requires that you implement the parameters and properties properties and at least one sampler method; the class provides the unimplemented methods as mixins.

Creating a Sampler

The Sampler abstract base class (see abc) helps you create new dimod samplers.

Any new dimod sampler must define a subclass of Sampler that implements abstract properties parameters and properties and one of the abstract methods sample(), sample_ising(), or sample_qubo(). The Sampler class provides the complementary methods as mixins and ensures consistent responses.

For example, the following steps show how to easily create a dimod sampler. It is sufficient to implement a single method (in this example the sample_ising() method) to create a dimod sampler with the Sampler class.

class LinearIsingSampler(dimod.Sampler):
    
    def sample_ising(self, h, J):
        sample = linear_ising(h, J)
        energy = dimod.ising_energy(sample, h, J)
        return dimod.SampleSet.from_samples([sample], energy=[energy])

    @property
    def properties(self):
        return dict()

    @property
    def parameters(self):
        return dict()

For this example, the implemented sampler sample_ising() can be based on a simple placeholder function, which returns a sample that minimizes the linear terms:
def linear_ising(h, J):
    sample = {}
    for v in h:
        if h[v] < 0:
            sample[v] = +1
        else:
            sample[v] = -1
    return sample

The Sampler ABC provides the other sample methods “for free” as mixins.

sampler = LinearIsingSampler()
response = sampler.sample_ising({'a': -1}, {}) # Implemented by class
response = sampler.sample_qubo({('a', 'a'): 1}) # Mixin provided by Sampler class
response = sampler.sample(BinaryQuadraticModel.from_ising({'a': -1}, {})) # Mixin

Below is a more complex version of the same sampler, where the properties and parameters properties return non-empty dicts.

class FancyLinearIsingSampler(dimod.Sampler):
    def __init__(self):
        self._properties = {'description': 'a simple sampler that only considers the
linear terms'}
        self._parameters = {'verbose': []}

    def sample_ising(self, h, J, verbose=False):
        sample = linear_ising(h, J)
        energy = dimod.ising_energy(sample, h, J)
        if verbose:
            print(sample)
        return dimod.SampleSet.from_samples([sample], energy=[energy])

@property
def properties(self):
    return self._properties

@property
def parameters(self):
    return self._parameters

class Sampler
    Abstract base class for dimod samplers.

    Provides all methods sample(), sample_ising(), sample_qubo() assuming at least one is implemented.

Abstract Properties

Sampler.parameters
    A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevent to each parameter.
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Table 48 – continued from previous page

| Sampler.properties | A dict containing any additional information about the sampler. |

**dimod.Sampler.parameters**

**Sampler.parameters**

A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.

Type dict

**dimod.Sampler.properties**

**Sampler.properties**

A dict containing any additional information about the sampler.

Type dict

**Mixin Methods**

<table>
<thead>
<tr>
<th>Sampler.sample(bqm, **parameters)</th>
<th>Sample from a binary quadratic model.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampler.sample_ising(h, J, **parameters)</td>
<td>Sample from an Ising model using the implemented sample method.</td>
</tr>
<tr>
<td>Sampler.sample_qubo(Q, **parameters)</td>
<td>Sample from a QUBO using the implemented sample method.</td>
</tr>
</tbody>
</table>

**dimod.Sampler.sample**

**Sampler.sample**(bqm, **parameters)

Sample from a binary quadratic model.

This method is inherited from the Sampler base class.

Converts the binary quadratic model to either Ising or QUBO format and then invokes an implemented sampling method (one of sample_ising() or sample_qubo()).

:param BinaryQuadraticModel: A binary quadratic model. :param **kwargs: See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also:

sample_ising(), sample_qubo()

**dimod.Sampler.sample_ising**

**Sampler.sample_ising**(h, J, **parameters)

Sample from an Ising model using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the Ising model into a BinaryQuadraticModel and then calls sample().
Parameters

- \( h \) (dict/list) – Linear biases of the Ising problem. If a dict, should be of the form \( \{v: \text{bias}, \ldots\} \) where \( v \) is a spin-valued variable and \( \text{bias} \) is its associated bias. If a list, it is treated as a list of biases where the indices are the variable labels.

- \( J \) (dict[(variable, variable), bias]) – Quadratic biases of the Ising problem.

- **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also: sample(), sample_qubo()

dimod.Sampler.sample_qubo

Sampler.sample_qubo(Q, **parameters)

Sample from a QUBO using the implemented sample method.

This method is inherited from the Sampler base class.

Converts the QUBO into a BinaryQuadraticModel and then calls sample().

Parameters

- \( Q \) (dict) – Coefficients of a quadratic unconstrained binary optimization (QUBO) problem. Should be a dict of the form \( \{(u, v): \text{bias}, \ldots\} \) where \( u, v \) are binary-valued variables and \( \text{bias} \) is their associated coefficient.

- **kwargs – See the implemented sampling for additional keyword definitions.

Returns SampleSet

See also: sample(), sample_ising()

Creating a Composed Sampler

Samplers can be composed. The composite pattern allows layers of pre- and post-processing to be applied to binary quadratic programs without needing to change the underlying sampler implementation.

We refer to these layers as composites. Each composed sampler must include at least one sampler, and possibly many composites.

Each composed sampler is itself a dimod sampler with all of the included methods and parameters. In this way complex samplers can be constructed.

The dimod ComposedSampler abstract base class inherits from Sampler class its abstract methods, properties, and mixins (for example, a sample_Ising method) and from Composite class the children property and child mixin (children being a list of supported samplers with child providing the first).

Examples

The dimod package’s spin_transform.py reference example creates a composed sampler, SpinReversalTransformComposite(Sampler, Composite), that performs spin reversal transforms (“gauge transformations”) as a preprocessing step for a given sampler. The reference example implements the pseudocode below:
Fig. 1: Composite Pattern
class SpinReversalTransformComposite(Sampler, Composite):
    
    # Updates to inherited sampler properties and parameters
    # Definition of the composite's children (i.e., supported samplers):
    children = None
    def __init__(self, child):
        self.children = [child]
    
    # The composite's implementation of spin-transformation functionality:
    def sample(self, bqm, num_spin_reversal_transforms=2, spin_reversal__variables=None, **kwars):
        response = None
        # Preprocessing code that includes instantiation of a sampler:
        # flipped_response = self.child.sample(bqm, **kwars)
        return response

Given a sampler, sampler1, the composed sampler is used as any dimod sampler. For example, the composed sampler inherits an Ising sampling method:

```python
>>> composed_sampler = dimod.SpinReversalTransformComposite(sampler1)  # doctest: +SKIP
>>> h = {0: -1, 1: 1}  # doctest: +SKIP
>>> response = composed_sampler.sample_ising(h, {})  # doctest: +SKIP
```

class ComposedSampler
Abstract base class for dimod composed samplers.

    Inherits from Sampler and Composite.

class Composite
Abstract base class for dimod composites.

    Provides the Composite.child mixin property and defines the Composite.children abstract property
to be implemented. These define the supported samplers for the composed sampler.

Abstract Properties

<table>
<thead>
<tr>
<th>Composite.children</th>
<th>List of child samplers that that are used by this composite.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>dimod.Composite.children</th>
</tr>
</thead>
</table>

Composite.children
List of child samplers that that are used by this composite.

    Type list[ Sampler]

Mixin Properties

<table>
<thead>
<tr>
<th>Composite.child</th>
<th>The child sampler.</th>
</tr>
</thead>
</table>
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**dimod.Composite.child**

Composite.child

The child sampler. First sampler in Composite.children.

Type Sampler

Creating a Structured Sampler

A structured sampler can only sample from binary quadratic models with a specific graph.

For structured samplers you must implement the nodelist and edgelist properties. The Structured abstract base class provides access to the structure and adjacency properties as well as any method or properties required by the Sampler abstract base class. The bqm_structured decorator verifies that any given binary quadratic model conforms to the supported structure.

Examples

This simple example shows a structured sampler that can only sample from a binary quadratic model with two variables and one interaction.

```python
class TwoVariablesSampler(dimod.Sampler, dimod.Structured):
    @property
    def nodelist(self):
        return [0, 1]

    @property
    def edgelist(self):
        return [(0, 1)]

    @property
    def properties(self):
        return dict()

    @property
    def parameters(self):
        return dict()

    @dimod.decorators.bqm_structured
def sample(self, bqm):
        # All bqm's passed in will be a subgraph of the sampler's structure
        variable_list = list(bqm.linear)
        samples = []
        energies = []
        for values in itertools.product(bqm.vartype.value, repeat=len(bqm)):
            sample = dict(zip(variable_list, values))
            samples.append(sample)
            energies.append(bqm.energy(sample))

        return dimod.SampleSet.from_samples(samples, bqm.Vartype, energies)

    return response
```

**class Structured**

The abstract base class for dimod structured samplers.
Provides the `Structured.adjacency` and `Structured.structure` properties.

Abstract properties `nodelist` and `edgelist` must be implemented.

**Abstract Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Structured.nodelist</code></td>
<td>Nodes/variables allowed by the sampler.</td>
</tr>
<tr>
<td><code>Structured.edgelist</code></td>
<td>Edges/interactions allowed by the sampler in the form <code>{(u, v), ...}</code>.</td>
</tr>
</tbody>
</table>

**dimod.Structured.nodelist**

`Structured.nodelist`

Nodes/variables allowed by the sampler.

Type: list

**dimod.Structured.edgelist**

`Structured.edgelist`

Edges/interactions allowed by the sampler in the form `{(u, v), ...}`.

Type: list

**Mixin Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Structured.adjacency</code></td>
<td>Adjacency structure formatted as a dict, where keys are the nodes of the structured sampler and values are sets of all adjacent nodes for each key node.</td>
</tr>
<tr>
<td><code>Structured.structure</code></td>
<td>Structure of the structured sampler formatted as a namedtuple, <code>Structure(nodelist, edgelist, adjacency)</code>, where the 3-tuple values are the <code>nodelist</code>, <code>edgelist</code> and <code>adjacency</code> attributes.</td>
</tr>
</tbody>
</table>

**dimod.Structured.adjacency**

`Structured.adjacency`

Adjacency structure formatted as a dict, where keys are the nodes of the structured sampler and values are sets of all adjacent nodes for each key node.

Type: dict[variable, set]

**dimod.Structured.structure**

`Structured.structure`

Structure of the structured sampler formatted as a namedtuple, `Structure(nodelist, edgelist, adjacency)`, where the 3-tuple values are the `nodelist`, `edgelist` and `adjacency` attributes.
Creating a Binary Polynomial Sampler

Samplers that handle binary polynomials: problems with binary variables that are not constrained to quadratic interactions.

```python
class PolySampler
    Sampler that supports binary polynomials.
    Binary polynomials are an extension of binary quadratic models that allow higher-order interactions.
```

Abstract Properties

```python
dimod.PolySampler.parameters
    A dict where keys are the keyword parameters accepted by the sampler methods and values are lists of the properties relevant to each parameter.
    Type  dict

dimod.PolySampler.properties
    A dict containing any additional information about the sampler.
    Type  dict
```

Abstract Methods

```python
PolySampler.sample_poly (polynomial, **kwargs)  Sample from a higher-order polynomial.

dimod.PolySampler.sample_poly
```

Mixin Methods

```python
PolySampler.sample_hising (h, J, **kwargs)  Sample from a higher-order Ising model.
```

Continued on next page
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| `PolySampler.sample_hubo(H, **kwargs)` | Sample from a higher-order unconstrained binary optimization problem. |

**dimod.PolySampler.sample_hising**

`PolySampler.sample_hising(h, J, **kwargs)`  
Sample from a higher-order Ising model.

Convert the given higher-order Ising model to a `BinaryPolynomial` and call `sample_poly()`.

**Parameters**

- `h (dict)` – Variable biases of the Ising problem as a dict of the form `{v: bias, ...}`, where `v` is a variable in the polynomial and `bias` its associated coefficient.
- `J (dict)` – Interaction biases of the Ising problem as a dict of the form `{(u, v, ...): bias}`, where `u, v`, are spin-valued variables in the polynomial and `bias` their associated coefficient.
- `**kwargs` – See `sample_poly()` for additional keyword definitions.

**Returns** `SampleSet`

See also:  
`sample_poly()`, `sample_hubo()`

**dimod.PolySampler.sample_hubo**

`PolySampler.sample_hubo(H, **kwargs)`  
Sample from a higher-order unconstrained binary optimization problem.

Convert the given higher-order unconstrained binary optimization problem to a `BinaryPolynomial` and then call `sample_poly()`.

**Parameters**

- `H (dict)` – Coefficients of the HUBO as a dict of the form `{(u, ...): bias, ...}`, where `u, v`, are binary-valued variables in the polynomial and `bias` their associated coefficient.
- `**kwargs` – See `sample_poly()` for additional keyword definitions.

**Returns** `SampleSet`

See also:  
`sample_poly()`, `sample_hising()`

**Creating a Composed Binary Polynomial Sampler**

class ComposedPolySampler  
Abstract base class for dimod composed polynomial samplers.

Inherits from `PolySampler` and `Composite`.  

2.2.3 Samples

dimod samples sample from a problem’s objective function, such as a BQM, and return an iterable of samples contained in a SampleSet class. In addition to containing the returned solutions and some additional information, and providing methods to work with the solutions, SampleSet is also used, for example, by dwave-hybrid, which iterates sets of samples through samplers to solve arbitrary QUBOs. dimod provides functionality for creating and manipulating samples.

**Sample_like Objects**

**as_samples**(samples_like[, dtype, copy, order])  
Convert a samples_like object to a NumPy array and list of labels.

**dimod.as_samples**

**as_samples**(samples_like, dtype=None, copy=False, order='C')  
Convert a samples_like object to a NumPy array and list of labels.

**Parameters**

- **samples_like**(samples_like) – A collection of raw samples. samples_like is an extension of NumPy’s array_like structure. See examples below.
- **dtype**(data-type, optional) – dtype for the returned samples array. If not provided, it is either derived from samples_like, if that object has a dtype, or set to numpy.int8.
- **copy**(bool, optional, default=False) – If true, then samples_like is guaranteed to be copied, otherwise it is only copied if necessary.
- **order**(('K', 'A', 'C', 'F'), optional, default='C') – Specify the memory layout of the array. See numpy.array().

**Returns**

A 2-tuple containing:

- **numpy.ndarray**: Samples.
- **list**: Variable labels

**Return type** tuple

**Examples**

The following examples convert a variety of samples_like objects:

NumPy arrays

```python
>>> import numpy as np
... >>> dimod.as_samples(np.ones(5, dtype='int8'))
(array([[1, 1, 1, 1, 1]], dtype=int8), [0, 1, 2, 3, 4])
>>> dimod.as_samples(np.zeros((5, 2), dtype='int8'))
(array([[0, 0],
        [0, 0],
        [0, 0]], dtype=int8), [0, 1, 2, 3, 4])
```

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Lists

```python
>>> dimod.as_samples([-1, +1, -1])
(array([[-1,  1, -1]], dtype=int8), [0, 1, 2])
>>> dimod.as_samples([-1, +1, -1])
(array([[-1,  1],
       [-1]], dtype=int8), [0])
```

Dicts

```python
>>> dimod.as_samples({'a': 0, 'b': 1, 'c': 0})
# doctest: +SKIP
(array([[ 0,  1,  0]], dtype=int8), ['a', 'b', 'c'])
>>> dimod.as_samples({'a': -1, 'b': +1, 'a': 1, 'b': 1})
# doctest: +SKIP
(array([[ 1,  1]], dtype=int8), ['a', 'b'])
```

A 2-tuple containing an array_like object and a list of labels

```python
>>> dimod.as_samples(([-1, +1, -1], ['a', 'b', 'c']))
(array([[-1,  1, -1]], dtype=int8), ['a', 'b', 'c'])
>>> dimod.as_samples((np.zeros((5, 2), dtype='int8'), ['in', 'out']))
(array([[0, 0],
       [0, 0],
       [0, 0],
       [0, 0],
       [0, 0]], dtype=int8), ['in', 'out'])
```

SampleSet

```python
class SampleSet(record, variables, info, vartype)
```

Samples and any other data returned by dimod samplers.

Parameters

- **record** ([numpy.recarray](#)) – A NumPy record array. Must have ‘sample’, ‘energy’ and ‘num_occurrences’ as fields. The ‘sample’ field should be a 2D NumPy array where each row is a sample and each column represents the value of a variable.
- **variables** ([iterable](#)) – An iterable of variable labels, corresponding to columns in `record.samples`.
- **info** ([dict](#)) – Information about the `SampleSet` as a whole, formatted as a dict.
- **vartype** ([Vartype/str/set](#)) – Variable type for the `SampleSet`. Accepted input values:
  - `Vartype.SPIN`, `'SPIN'`, `{−1, 1}`
  - `Vartype.BINARY`, `'BINARY'`, `{0, 1}`

Examples

This example creates a SampleSet out of a samples_like object (a NumPy array).
```python
>>> import dimod
>>> import numpy as np
... # doctest: +SKIP
SampleSet(rec.array([(\[[1, 1, 1, 1, 1\]], 0, 1)],
... dtype=[('sample', 'i1', (5,)), ('energy', '<i4'), ('num_occurrences', '<i4')]),
... [0, 1, 2, 3, 4], {}, 'BINARY')
```

### Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SampleSet.first</td>
<td>Sample with the lowest-energy.</td>
</tr>
<tr>
<td>SampleSet.info</td>
<td>Dict of information about the SampleSet as a whole.</td>
</tr>
<tr>
<td>SampleSet.record</td>
<td>numpy.recarray containing the samples, energies, number of occurrences, and other sample data.</td>
</tr>
<tr>
<td>SampleSet.variables</td>
<td>VariableIndexView of variable labels.</td>
</tr>
<tr>
<td>SampleSet.vartype</td>
<td>Vartype of the samples.</td>
</tr>
</tbody>
</table>

#### dimod.SampleSet.first

SampleSet.\texttt{first}

Sample with the lowest-energy.

**Raises** `ValueError` – If empty.

#### dimod.SampleSet.info

SampleSet.\texttt{info}

Dict of information about the `SampleSet` as a whole.

#### Examples

This example shows the type of information that might be returned by a dimod sampler by submitting a BQM that sets a value on a D-Wave system’s first listed coupler.

```python
>>> from dwave.system.samplers import DWaveSampler
>>> sampler = DWaveSampler()
>>> bqm = dimod.BQM({}, {sampler.edgelist[0]: -1}, 0, dimod.SPIN)
>>> sampler.sample(bqm).info
{'timing': {'qpu_sampling_time': 315,
            'qpu_anneal_time_per_sample': 20,
            ...
```

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'dqpu_readout_time_per_sample': 274,
# Snipped above response for brevity

**dimod.SampleSet.record**

`SampleSet.record` is a `numpy.recarray` containing the samples, energies, number of occurrences, and other sample data.

**Examples**

```python
>>> import dimod
... >>> sampler = dimod.ExactSolver()
>>> sampleset = sampler.sample_ising({'a': -0.5, 'b': 1.0}, {('a', 'b'): -1.0})
>>> sampleset.record
rec.array([([-1, -1], -1.5, 1), ([ 1, -1], -0.5, 1), ([ 1, 1], -0.5, 1),
           ([1, 1], 2.5, 1)],
           dtype=[('sample', 'i1', (2,)), ('energy', '<f8'), ('num_occurrences', '<i8')])
```

**dimod.SampleSet.variables**

`SampleSet.variables` is a `VariableIndexView` of variable labels. It corresponds to columns of the sample field of `SampleSet.record`.

**dimod.SampleSet.vartype**

`SampleSet.vartype` is the vartype of the samples.

**Methods**

- `SampleSet.aggregate()` Create a new SampleSet with repeated samples aggregated.
- `SampleSet.append_variables(samples_like[, ...])` Create a new sampleset with the given variables and values.
- `SampleSet.change_vartype(vartype[, ...])` Return the SampleSet with the given vartype.
- `SampleSet.copy()` Create a shallow copy.

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<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>SampleSet.data</code></td>
<td>Iterate over the data in the SampleSet.</td>
</tr>
<tr>
<td><code>SampleSet.done()</code></td>
<td>Return True if a pending computation is done.</td>
</tr>
<tr>
<td><code>SampleSet.from_future</code></td>
<td>Construct a SampleSet referencing the result of a future computation.</td>
</tr>
<tr>
<td><code>SampleSet.from_samples</code></td>
<td>Build a SampleSet from raw samples.</td>
</tr>
<tr>
<td><code>SampleSet.from_samples_bqm</code></td>
<td>Build a sample set from raw samples and a binary quadratic model.</td>
</tr>
<tr>
<td><code>SampleSet.from_serializable</code></td>
<td>Deserialize a SampleSet.</td>
</tr>
<tr>
<td><code>SampleSet.lowest</code></td>
<td>Return a sample set containing the lowest-energy samples.</td>
</tr>
<tr>
<td><code>SampleSet.resolve()</code></td>
<td>Ensure that the sampleset is resolved if constructed from a future.</td>
</tr>
<tr>
<td><code>SampleSet.relabel_variables</code></td>
<td>Relabel the variables of a SampleSet according to the specified mapping.</td>
</tr>
<tr>
<td><code>SampleSet.samples</code></td>
<td>Return an iterable over the samples.</td>
</tr>
<tr>
<td><code>SampleSet.slice</code></td>
<td>Create a new sample set with rows sliced according to standard Python slicing syntax.</td>
</tr>
<tr>
<td><code>SampleSet.to_pandas_dataframe</code></td>
<td>Convert a sample set to a Pandas DataFrame</td>
</tr>
<tr>
<td><code>SampleSet.to_serializable</code></td>
<td>Convert a SampleSet to a serializable object.</td>
</tr>
<tr>
<td><code>SampleSet.truncate</code></td>
<td>Create a new sample set with up to n rows.</td>
</tr>
<tr>
<td><code>SampleSet.aggregate</code></td>
<td>Create a new SampleSet with repeated samples aggregated.</td>
</tr>
</tbody>
</table>

**Returns** SampleSet

**Note:** SampleSet.record.num_occurrences are accumulated but no other fields are.

**Examples**

This example aggregates a sample set with two identical samples out of three.

```
>>> sampleset = dimod.SampleSet.from_samples([[0, 0, 1], [0, 0, 1],
                                             [1, 1, 1],
                                             [0, 0, 1]),
                                             dimod.BINARY,
                                             [0, 0, 1])
>>> print(sampleset)
    0 1 2 energy num_oc.
    0 0 0 1 0 1
    1 0 0 1 0 1
    2 1 1 1 1 1
['BINARY', 3 rows, 3 samples, 3 variables]
>>> print(sampleset.aggregate())
    0 1 2 energy num_oc.
    0 0 0 1 0 2
    1 1 1 1 1 1
['BINARY', 2 rows, 3 samples, 3 variables]
```
dimod.SampleSet.append_variables

SampleSet.append_variables(samples_like, sort_labels=True)

Create a new sampleset with the given variables and values.

Not defined for empty sample sets. If sample_like is a SampleSet, its data vectors and info are ignored.

Parameters

- **samples_like** – Samples to add to the sample set. Either a single sample or identical in length to the sample set. ‘samples_like’ is an extension of NumPy’s array_like. See as_samples().

- **sort_labels** (bool, optional, default=True) – Return SampleSet.variables in sorted order. For mixed (unsortable) types, the given order is maintained.

Returns

New sample set with the variables/values added.

Return type SampleSet

Examples

```python
>>> sampleset = dimod.SampleSet.from_samples([{'a': -1, 'b': +1},
...                                           {'a': +1, 'b': +1}]
...                                           dimod.SPIN,
...                                           energy=[-1.0, 1.0])
>>> new = sampleset.append_variables({'c': -1})
>>> print(new)
[['SPIN', 2 rows, 2 samples, 3 variables]]
```

Add variables from another sample set to the previous example. Note that the energies remain unchanged.

```python
>>> another = dimod.SampleSet.from_samples([{'c': -1, 'd': +1},
...                                         {'c': +1, 'd': +1}]
...                                         dimod.SPIN,
...                                         energy=[-2.0, 1.0])
>>> new = sampleset.append_variables(another)
>>> print(new)
[['SPIN', 2 rows, 2 samples, 4 variables]]
```

dimod.SampleSet.change_vartype

SampleSet.change_vartype(vartype, energy_offset=0.0, inplace=True)

Return the SampleSet with the given vartype.

Parameters

- **vartype** (Vartype/str/set) – Variable type to use for the new SampleSet. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
- Vartype.BINARY, 'BINARY', {0, 1}

- energy_offset(number, optional, default=0.0) – Constant value applied to the ‘energy’ field of SampleSet.record.

- inplace (bool, optional, default=True) – If True, the instantiated SampleSet is updated; otherwise, a new SampleSet is returned.

Returns SampleSet with changed vartype. If inplace is True, returns itself.

Return type SampleSet

Examples

This example creates a binary copy of a spin-valued SampleSet.

```python
>>> import dimod
... >>> sampleset = dimod.ExactSolver().sample_ising({'a': -0.5, 'b': 1.0}, {('a', 'b'): -1})
... >>> sampleset_binary = sampleset.change_vartype(dimod.BINARY, energy_offset=1.0, inplace=False)
... >>> sampleset_binary.vartype is dimod.BINARY
True
... >>> for datum in sampleset_binary.data(fields=['sample', 'energy', 'num_occurrences']):
...     # doctest: +SKIP
...     print(datum)
Sample(sample={'a': 0, 'b': 0}, energy=-0.5, num_occurrences=1)
Sample(sample={'a': 1, 'b': 0}, energy=0.5, num_occurrences=1)
Sample(sample={'a': 1, 'b': 1}, energy=0.5, num_occurrences=1)
Sample(sample={'a': 0, 'b': 1}, energy=3.5, num_occurrences=1)
```

dimod.SampleSet.copy

SampleSet.copy()  
Create a shallow copy.

dimod.SampleSet.data

SampleSet.data(fields=None, sorted_by='energy', name='Sample', reverse=False, sample_dict_cast=True, index=False)

Iterate over the data in the SampleSet.

Parameters

- fields(list, optional, default=None) – If specified, only these fields are included in the yielded tuples. The special field name ‘sample’ can be used to view the samples.

- sorted_by(str/None, optional, default='energy') – Selects the record field used to sort the samples. If None, the samples are yielded in record order.

- name(str/None, optional, default='Sample') – Name of the yielded namedtuples or None to yield regular tuples.

- reverse(bool, optional, default=False) – If True, yield in reverse order.
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- **sample_dict_cast**(bool, optional, default=True) – Samples are returned as dicts rather than SampleView, which requires heavy memory usage. Set to False to reduce load on memory.

- **index**(bool, optional, default=False) – If True, datum.idx gives the corresponding index of the SampleSet.record.

Yields namedtuple/tuple – The data in the SampleSet, in the order specified by the input fields.

Examples

```python
>>> import dimod
... >>> sampleset = dimod.ExactSolver().sample_ising({'a': -0.5, 'b': 1.0}, {('a', 'b →'): -1})
>>> for datum in sampleset.data(fields=['sample', 'energy']):  # doctest: +SKIP
... print(datum)
Sample(sample={'a': -1, 'b': -1}, energy=-1.5)
Sample(sample={'a': 1, 'b': -1}, energy=-0.5)
Sample(sample={'a': 1, 'b': 1}, energy=-0.5)
Sample(sample={'a': -1, 'b': 1}, energy=2.5)
>>> for energy, in sampleset.data(fields=['energy'], sorted_by='energy'):
... print(energy)
... -1.5
-0.5
-0.5
2.5
>>> print(next(sampleset.data(fields=['energy'], name='ExactSolverSample')))
ExactSolverSample(energy=-1.5)
```

dimod.SampleSet.done

SampleSet.done() Return True if a pending computation is done. Used when a SampleSet is constructed with SampleSet.from_future().

Examples

This example uses a Future object directly. Typically a Executor sets the result of the future (see documentation for concurrent.futures).

```python
>>> import dimod
>>> from concurrent.futures import Future
... >>> future = Future()
>>> sampleset = dimod.SampleSet.from_future(future)
>>> future.done()
False
>>> future.set_result(dimod.ExactSolver().sample_ising({0: -1}, {}))
>>> future.done()
True
>>> sampleset.record.sample
```

(continues on next page)
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(continued from previous page)

```python
array([[ 1],
       [-1]], dtype=int8)
```

dimod.SampleSet.from_future

classmethod SampleSet.from_future(future, result_hook=None)

Construct a SampleSet referencing the result of a future computation.

Parameters

- **future** *(object)* – Object that contains or will contain the information needed to construct a SampleSet. If future has a done() method, this determines the value returned by SampleSet.done().

- **result_hook** *(callable, optional)* – A function that is called to resolve the future. Must accept the future and return a SampleSet. If not provided, set to

  ```python
def result_hook(future):
    return future.result()
```

Returns **SampleSet**

Notes

The future is resolved on the first read of any of the SampleSet properties.

Examples

Run a dimod sampler on a single thread and load the returned future into SampleSet.

```python
>>> import dimod
>>> from concurrent.futures import ThreadPoolExecutor
...  bqm = dimod.BinaryQuadraticModel.from_ising({}, {('a', 'b'): -1})
>>> with ThreadPoolExecutor(max_workers=1) as executor:
...    future = executor.submit(dimod.ExactSolver().sample, bqm)
...    sampleset = dimod.SampleSet.from_future(future)
```  

```python
array([[-1, -1],
       [ 1, 1],
       [-1, 1],
       [ 1, -1]],
       dtype='i1')
```

dimod.SampleSet.from_samples

classmethod SampleSet.from_samples(samples_like, vartype, energy, info=None, num_occurrences=None, aggregate_samples=False, sort_labels=True, **vectors)

Build a SampleSet from raw samples.

Parameters
• **samples_like** – A collection of raw samples. ‘samples_like’ is an extension of NumPy’s array_like. See as_samples().

• **vartype** *(Vartype/str/set)* – Variable type for the SampleSet. Accepted input values:
  – Vartype.SPIN, 'SPIN', {-1, 1}
  – Vartype.BINARY, 'BINARY', {0, 1}

• **energy** *(array_like)* – Vector of energies.

• **info** *(dict, optional)* – Information about the SampleSet as a whole formatted as a dict.

• **num_occurrences** *(array_like, optional)* – Number of occurrences for each sample. If not provided, defaults to a vector of 1s.

• **aggregate_samples** *(bool, optional, default=False)* – If True, all samples in returned SampleSet are unique, with num_occurrences accounting for any duplicate samples in samples_like.

• **sort_labels** *(bool, optional, default=True)* – Return SampleSet variables in sorted order. For mixed (unsortable) types, the given order is maintained.

• **vectors** *(array_like)* – Other per-sample data.

**Returns** SampleSet

**Examples**

This example creates a SampleSet out of a samples_like object (a dict).

```python
>>> import dimod
>>> import numpy as np
...
>>> dimod.SampleSet.from_samples(dimod.as_samples({'a': 0, 'b': 1, 'c': 0}), 'BINARY', 0)
# doctest: +SKIP
SampleSet(rec.array([[0, 1, 0], 0, 1]), ... dtype=[('sample', 'i1', (3,)), ('energy', '<i4'), ('num_occurrences', '<i4')], ... ['a', 'b', 'c'], {}, 'BINARY')
```

**dimod.SampleSet.from_samples_bqm**

**classmethod SampleSet.from_samples_bqm**(samples_like, bqm, **kwargs)

Build a sample set from raw samples and a binary quadratic model.

The binary quadratic model is used to calculate energies and set the vartype.

**Parameters**

• **samples_like** – A collection of raw samples. ‘samples_like’ is an extension of NumPy’s array_like. See as_samples().

• **bqm** *(BinaryQuadraticModel)* – A binary quadratic model.

• **info** *(dict, optional)* – Information about the SampleSet as a whole formatted as a dict.

• **num_occurrences** *(array_like, optional)* – Number of occurrences for each sample. If not provided, defaults to a vector of 1s.
• **aggregate_samples** (*bool*, optional, default=False) – If True, all samples in returned `SampleSet` are unique, with `num_occurrences` accounting for any duplicate samples in `samples_like`.

• **sort_labels** (*bool*, optional, default=True) – Return `SampleSet` variables in sorted order. For mixed (unsortable) types, the given order is maintained.

• **vectors** (*array_like*) – Other per-sample data.

Returns `SampleSet`

**Examples**

```python
def main():
    import dimod
    bqm = dimod.BinaryQuadraticModel.from_ising({}, {('a', 'b'): -1})
    samples = dimod.SampleSet.from_samples_bqm({'a': -1, 'b': 1}, bqm)
    dimod.SampleSet.from_serializable

def SampleSet.from_serializable(cls, obj):
    return cls.obj

Examples

This example encodes and decodes using JSON.

```python
def main():
    import dimod
    import json
    ...  
    s = json.dumps(samples.to_serializable())
    new_samples = dimod.SampleSet.from_serializable(json.loads(s))

See also:

to_serializable()```
Returns A new sample set containing the lowest energy samples as delimited by configured tolerances from the lowest energy sample in the current sample set.

Return type SampleSet

Examples

```python
>>> sampleset = dimod.ExactSolver().sample_ising({'a': .001},
       ...       {('a', 'b'): -1})
>>> print(sampleset.lowest())
a b energy num_oc.
0 -1 -1 -1.001 1
['SPIN', 1 rows, 1 samples, 2 variables]
>>> print(sampleset.lowest(atol=.1))
a b energy num_oc.
0 -1 -1 -1.001 1
1 +1 +1 -0.999 1
['SPIN', 2 rows, 2 samples, 2 variables]
```

Note: “Lowest energy” is the lowest energy in the sample set. This is not always the “ground energy” which is the lowest energy possible for a binary quadratic model.

dimod.SampleSet.resolve

SampleSet.resolve()

Ensure that the sampleset is resolved if constructed from a future.

dimod.SampleSet.relabel_variables

SampleSet.relabel_variables(mapping, inplace=True)

Relabel the variables of a SampleSet according to the specified mapping.

Parameters

- mapping (dict) – Mapping from current variable labels to new, as a dict. If incomplete mapping is specified, unmapped variables keep their current labels.
- inplace (bool, optional, default=True) – If True, the current SampleSet is updated; otherwise, a new SampleSet is returned.

Returns SampleSet with relabeled variables. If inplace is True, returns itself.

Return type SampleSet

Examples

This example creates a relabeled copy of a SampleSet.

```python
>>> import dimod
... >>> sampleset = dimod.ExactSolver().sample_ising({'a': -0.5, 'b': 1.0}, {('a', 'b'): -1})
```
```python
dimod.ExactSolver().sample_ising({'a': -1, 'b': 1})
```
• `stop (int)` – Stop index for `slice`.
• `step (int, optional, default=None)` – Step value for `slice`.
• `sorted_by (str/None, optional, default='energy')` – Selects the record field used to sort the samples before slicing. Note that `sorted_by` determines the sample order in the returned sample set.

Returns `SampleSet`

Examples

```python
>>> import numpy as np
...
>>> sampleset = dimod.SampleSet.from_samples(np.diag(range(1, 11)),
...                                          dimod.BINARY, energy=range(10))
>>> print(sampleset)
0 1 2 3 4 5 6 7 8 9  energy  num_oc.
0 1 0 0 0 0 0 0 0 0 0 1 0
1 0 1 0 0 0 0 0 0 0 0 1 1
2 0 0 1 0 0 0 0 0 0 0 2 1
3 0 0 0 1 0 0 0 0 0 0 3 1
4 0 0 0 0 1 0 0 0 0 0 4 1
5 0 0 0 0 0 1 0 0 0 0 5 1
6 0 0 0 0 0 0 1 0 0 0 6 1
7 0 0 0 0 0 0 0 1 0 0 7 1
8 0 0 0 0 0 0 0 0 1 0 8 1
9 0 0 0 0 0 0 0 0 0 1 9 1
['BINARY', 10 rows, 10 samples, 10 variables]

The above example’s first 3 samples by energy == truncate(3):

```python
>>> print(sampleset.slice(3))
0 1 2 3 4 5 6 7 8 9  energy  num_oc.
0 1 0 0 0 0 0 0 0 0 0 1 0
1 0 1 0 0 0 0 0 0 0 0 1 1
2 0 0 1 0 0 0 0 0 0 0 2 1
['BINARY', 3 rows, 3 samples, 10 variables]
```

The last 3 samples by energy:

```python
>>> print(sampleset.slice(-3, None))
0 1 2 3 4 5 6 7 8 9  energy  num_oc.
0 0 0 0 0 0 0 0 1 0 0 7 1
1 0 0 0 0 0 0 0 1 0 0 8 1
2 0 0 0 0 0 0 0 0 1 0 9 1
['BINARY', 3 rows, 3 samples, 10 variables]
```

Every second sample in between, skipping top and bottom 3:

```python
>>> print(sampleset.slice(3, -3, 2))
0 1 2 3 4 5 6 7 8 9  energy  num_oc.
0 0 0 0 1 0 0 0 0 0 3 1
1 0 0 0 0 1 0 0 0 0 5 1
['BINARY', 2 rows, 2 samples, 10 variables]
```
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dimod.SampleSet.to_pandas_dataframe

SampleSet.to_pandas_dataframe(sample_column=False)
Convert a sample set to a Pandas DataFrame

Parameters

- sample_column (bool, optional, default=False) – If True, samples are
  as a column of type dict.

Returns pandas.DataFrame

Examples

```python
>>> samples = dimod.SampleSet.from_samples({
    {'a': -1, 'b': +1, 'c': -1},
    {'a': -1, 'b': -1, 'c': +1}
}, dimod.SPIN, energy=-.5)
```

```plaintext
a b c energy num_occurrences
0 -1 1 -1 -0.5 1
1 -1 -1 1 -0.5 1
```

```python
>>> samples.to_pandas_dataframe(sample_column=True)
```

```plaintext
sample energy num_occurrences
0 {'a': -1, 'b': 1, 'c': -1} -0.5 1
1 {'a': -1, 'b': -1, 'c': 1} -0.5 1
```

dimod.SampleSet.to_serializable

SampleSet.to_serializable(use_bytes=False, bytes_type=bytes)
Convert a SampleSet to a serializable object.

Note that the contents of the SampleSet.info field are assumed to be serializable.

Parameters

- use_bytes (bool, optional, default=False) – If True, a compact representation of the biases as bytes is used.

- bytes_type (class, optional, default=bytes) – If use_bytes is True, this class is used to wrap the bytes objects in the serialization. Useful for Python 2 using BSON encoding, which does not accept the raw bytes type; bson.Binary can be used instead.

Returns Object that can be serialized.

Return type dict

Examples

This example encodes using JSON.

```python
>>> import dimod
>>> import json
... >>> samples = dimod.SampleSet.from_samples([-1, 1, -1], dimod.SPIN, energy=-.5)
>>> s = json.dumps(samples.to_serializable())
```
See also:

\[\text{from_serializable()}\]

dimod.SampleSet.truncate

**SampleSet.truncate(n, sorted_by='energy')**

Create a new sample set with up to \(n\) rows.

**Parameters**

- \(n\) (*int*) – Maximum number of rows in the returned sample set. Does not return any rows above this limit in the original sample set.

- **sorted_by** (*str/None, optional, default='energy'*) – Selects the record field used to sort the samples before truncating. Note that this sort order is maintained in the returned sample set.

**Returns** *SampleSet*

**Examples**

```python
gs = dimod.SampleSet.from_samples(np.ones((5, 5)), dimod.SPIN,
   energy=5)
print(gs)
# 0 1 2 3 4 energy num_oc.
# 0 +1 +1 +1 +1 +1 5 1
# 1 +1 +1 +1 +1 +1 5 1
# 2 +1 +1 +1 +1 +1 5 1
# 3 +1 +1 +1 +1 +1 5 1
# 4 +1 +1 +1 +1 +1 5 1
# ['SPIN', 5 rows, 5 samples, 5 variables]
print(gs.truncate(2))
# 0 1 2 3 4 energy num_oc.
# 0 +1 +1 +1 +1 +1 5 1
# 1 +1 +1 +1 +1 +1 5 1
# ['SPIN', 2 rows, 2 samples, 5 variables]
```

See: *SampleSet.slice()*

**Utility Functions**

```python
dimod.concatenate

\[\text{concatenate(samplesets[, defaults])}\]

Combine sample sets.

**Example**

```python
c = dimod.concatenate([gs1, gs2], defaults=gs1)
```
• **defaults** *(dict, optional)* – Dictionary mapping data vector names to the corresponding default values.

**Returns** A sample set with the same vartype and variable order as the first given in *samplesets*.

**Return type** *SampleSet*

## Examples

```python
>>> a = dimod.SampleSet.from_samples(([-1, +1], 'ab'), dimod.SPIN, energy=-1)
>>> b = dimod.SampleSet.from_samples(([-1, +1], 'ba'), dimod.SPIN, energy=-1)
>>> ab = dimod.concatenate((a, b))
>>> ab.record.sample
array([[-1,  1],
       [ 1, -1]], dtype=int8)
```

### 2.2.4 Higher-Order Models

Sometimes it is nice to work with problems that are not restricted to quadratic interactions.

#### Binary Polynomials

**class** *BinaryPolynomial*(poly, vartype)*

A polynomial with binary variables and real-valued coefficients.

**Parameters**

- **poly** *(mapping/iterable)* – Polynomial as a mapping of form `{term: bias, . . .}`, where *term* is a collection of variables and *bias* the associated bias. It can also be an iterable of 2-tuples (term, bias).
- **vartype** *(Vartype/str/set)* – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}

**degree**

The degree of the polynomial.

Type **int**

**variables**

The variables.

Type **set**

**vartype**

One of Vartype.SPIN or Vartype.BINARY.

Type **Vartype**

## Examples

Binary polynomials can be constructed in many different ways. The following are all equivalent
Binary polynomials act a mutable mappings but the terms can be accessed with any sequence.

Methods

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<td>The energies of the given samples.</td>
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<td>Return a binary polynomial over {-1, +1} variables.</td>
</tr>
</tbody>
</table>
dimod.higherorder.polynomial.BinaryPolynomial.energies

BinaryPolynomial.energies(samples_like, dtype=<class 'float'>)
The energies of the given samples.

Parameters

- **samples_like** (samples_like) – A collection of raw samples. samples_like is an extension of NumPy’s array_like structure. See as_samples()
- **dtype** (numpy.dtype, optional) – The data type of the returned energies. Defaults to float.

Returns The energies.

Return type numpy.ndarray

dimod.higherorder.polynomial.BinaryPolynomial.energy

BinaryPolynomial.energy(sample_like, dtype=<class 'float'>)
The energy of the given sample.

Parameters

- **sample_like** (samples_like) – A raw sample. sample_like is an extension of NumPy’s array_like structure. See as_samples()
- **dtype** (numpy.dtype, optional) – The data type of the returned energies. Defaults to float.

Returns The energy.

dimod.higherorder.polynomial.BinaryPolynomial.from_hising

classmethod BinaryPolynomial.from_hising(h, J, offset=None)
Construct a binary polynomial from a higher-order Ising problem.

Parameters

- **h** (dict) – The linear biases.
- **J** (dict) – The higher-order biases.
- **offset** (optional, default=0.0) – Constant offset applied to the model.

Returns BinaryPolynomial

Examples

```python
>>> poly = dimod.BinaryPolynomial.from_hising({'a': 2}, {'ab': -1}, 0)
```

dimod.higherorder.polynomial.BinaryPolynomial.from_hubo

classmethod BinaryPolynomial.from_hubo(H, offset=None)
Construct a binary polynomial from a higher-order unconstrained binary optimization (HUBO) problem.
Parameters $H$ (dict) – Coefficients of a higher-order unconstrained binary optimization (HUBO) model.

Returns $\text{BinaryPolynomial}$

Examples

```python
>>> poly = dimod.BinaryPolynomial.from_hubo({('a', 'b', 'c'): -1})
```

$\text{dimod.higherorder.polynomial.BinaryPolynomial.normalize}$

$\text{BinaryPolynomial.normalize}(bias\_range=1, poly\_range=None, ignored\_terms=None)$

Normalizes the biases of the binary polynomial such that they fall in the provided range(s).

If $poly\_range$ is provided, then $bias\_range$ will be treated as the range for the linear biases and $poly\_range$ will be used for the range of the other biases.

Parameters

- $bias\_range$ (number/pair) – Value/range by which to normalize the all the biases, or if $poly\_range$ is provided, just the linear biases.
- $poly\_range$ (number/pair, optional) – Value/range by which to normalize the higher order biases.
- $ignored\_terms$ (iterable, optional) – Biases associated with these terms are not scaled.

$\text{dimod.higherorder.polynomial.BinaryPolynomial.relabel\_variables}$

$\text{BinaryPolynomial.relabel\_variables}(mapping, inplace=True)$

Relabel variables of a binary polynomial as specified by mapping.

Parameters

- $mapping$ (dict) – Dict mapping current variable labels to new ones. If an incomplete mapping is provided, unmapped variables retain their current labels.
- $inplace$ (bool, optional, default=True) – If True, the binary polynomial is updated in-place; otherwise, a new binary polynomial is returned.

Returns A binary polynomial with the variables relabeled. If $inplace$ is set to True, returns itself.

Return type $\text{BinaryPolynomial}$

$\text{dimod.higherorder.polynomial.BinaryPolynomial.scale}$

$\text{BinaryPolynomial.scale}(scalar, ignored\_terms=None)$

Multiply the polynomial by the given scalar.

Parameters

- $scalar$ (number) – Value to multiply the polynomial by.
- $ignored\_terms$ (iterable, optional) – Biases associated with these terms are not scaled.
dimod.higherorder.polynomial.BinaryPolynomial.to_binary

**BinaryPolynomial.to_binary** *(copy=False)*

Return a binary polynomial over \{0, 1\} variables.

**Parameters**
- **copy** *(optional, default=False)* – If True, the returned polynomial is always a copy. Otherwise, if the polynomial is binary-valued already it returns itself.

**Returns** *BinaryPolynomial*

dimod.higherorder.polynomial.BinaryPolynomial.to_hising

**BinaryPolynomial.to_hising**

Construct a higher-order Ising problem from a binary polynomial.

**Returns** A 3-tuple of the form \((h, J, \text{offset})\) where \(h\) includes the linear biases, \(J\) has the higher-order biases and \(\text{offset}\) is the linear offset.

**Return type** *tuple*

**Examples**

```python
>>> poly = dimod.BinaryPolynomial({'a': -1, 'ab': 1, 'abc': -1}, dimod.SPIN)
>>> h, J, off = poly.to_hising()
>>> h
{'a': -1}
```

dimod.higherorder.polynomial.BinaryPolynomial.to_hubo

**BinaryPolynomial.to_hubo**

Construct a higher-order unconstrained binary optimization (HUBO) problem from a binary polynomial.

**Returns** A 2-tuple of the form \((H, \text{offset})\) where \(H\) is the HUBO and \(\text{offset}\) is the linear offset.

**Return type** *tuple*

dimod.higherorder.polynomial.BinaryPolynomial.to_spin

**BinaryPolynomial.to_spin** *(copy=False)*

Return a binary polynomial over \{-1, +1\} variables.

**Parameters**
- **copy** *(optional, default=False)* – If True, the returned polynomial is always a copy. Otherwise, if the polynomial is spin-valued already it returns itself.

**Returns** *BinaryPolynomial*

Reducing to a Binary Quadratic Model

**make_quadratic** *(poly, strength[, vartype, bqm])* Create a binary quadratic model from a higher order polynomial.
dimod.higherorder.utils.make_quadratic

make_quadratic(poly, strength, vartype=None, bqm=None)
Create a binary quadratic model from a higher order polynomial.

Parameters

- **poly** (*dict*) – Polynomial as a dict of form `{term: bias, ...}`, where `term` is a tuple of variables and `bias` the associated bias.
- **strength** (*float*) – The energy penalty for violating the product constraint. Insufficient strength can result in the binary quadratic model not having the same minimizations as the polynomial.
- **vartype** (*Vartype/str/set, optional*) – Variable type for the binary quadratic model. Accepted input values:
  - Vartype.SPIN, 'SPIN', {-1, 1}
  - Vartype.BINARY, 'BINARY', {0, 1}
  If `bqm` is provided, `vartype` is not required.
- **bqm** (*BinaryQuadraticModel, optional*) – The terms of the reduced polynomial are added to this binary quadratic model. If not provided, a new binary quadratic model is created.

Returns

*BinaryQuadraticModel*

Examples

```python
>>> poly = {(0,): -1, (1,): 1, (2,): 1.5, (0, 1): -1, (0, 1, 2): -2}
>>> bqm = dimod.make_quadratic(poly, 5.0, dimod.SPIN)
```

2.2.5 Utilities

Contents

- **Utilities**
  - Energy Calculations
  - Decorators
  - Graph-like
  - Serialization
    - *JSON*
  - Testing
    - *API Asserts*
    - *Correctness Asserts*
  - Vartype Conversion
Energy Calculations

**dimod.utilities.ising_energy**

**isng_energy** *(sample, h, J[, offset]*)

Calculate the energy for the specified sample of an Ising model.

Energy of a sample for a binary quadratic model is defined as a sum, offset by the constant energy offset associated with the model, of the sample multiplied by the linear bias of the variable and all its interactions. For an Ising model,

\[ E(s) = \sum_v h_v s_v + \sum_{u,v} J_{u,v} s_u s_v + c \]

where \( s_v \) is the sample, \( h_v \) is the linear bias, \( J_{u,v} \) the quadratic bias (interactions), and \( c \) the energy offset.

- **Parameters**
  - **sample** *(dict[variable, spin]*) – Sample for a binary quadratic model as a dict of form \{v: spin, ...\}, where keys are variables of the model and values are spins (either -1 or 1).
  - **h** *(dict[variable, bias]*) – Linear biases as a dict of the form \{v: bias, ...\}, where keys are variables of the model and values are biases.
  - **J** *(dict[[variable, variable], bias]*) – Quadratic biases as a dict of the form \{(u, v): bias, ...\}, where keys are 2-tuples of variables of the model and values are quadratic biases associated with the pair of variables (the interaction).
  - **offset** *(numeric, optional, default=0*) – Constant offset to be applied to the energy. Default 0.

- **Returns** The induced energy.

- **Return type** *float*

- **Notes**

  No input checking is performed.

- **Examples**

  This example calculates the energy of a sample representing two down spins for an Ising model of two variables that have positive biases of value 1 and are positively coupled with an interaction of value 1.

  ```python
  >>> import dimod
  >>> sample = {1: -1, 2: -1}
  >>> h = {1: 1, 2: 1}
  >>> J = {(1, 2): 1}
  >>> dimod.ising_energy(sample, h, J, 0.5)
  -0.5
  ```
References

Ising model on Wikipedia

dimod.utilities.qubo_energy

qubo_energy(sample, Q, offset=0.0)

Calculate the energy for the specified sample of a QUBO model.

Energy of a sample for a binary quadratic model is defined as a sum, offset by the constant energy offset associated with the model, of the sample multiplied by the linear bias of the variable and all its interactions. For a quadratic unconstrained binary optimization (QUBO) model,

\[ E(x) = \sum_{u,v} Q_{u,v} x_u x_v + c \]

where \( x_v \) is the sample, \( Q_{u,v} \) a matrix of biases, and \( c \) the energy offset.

Parameters

- **sample** (dict[variable, spin]) – Sample for a binary quadratic model as a dict of form {v: bin, ...}, where keys are variables of the model and values are binary (either 0 or 1).
- **Q** (dict[(variable, variable), coefficient]) – QUBO coefficients in a dict of form {(u, v): coefficient, ...}, where keys are 2-tuples of variables of the model and values are biases associated with the pair of variables. Tuples (u, v) represent interactions and (v, v) linear biases.
- **offset** (numeric, optional, default=0) – Constant offset to be applied to the energy. Default 0.

Returns

The induced energy.

Return type

float

Notes

No input checking is performed.

Examples

This example calculates the energy of a sample representing two zeros for a QUBO model of two variables that have positive biases of value 1 and are positively coupled with an interaction of value 1.

```python
>>> import dimod
>>> sample = {1: 0, 2: 0}
>>> Q = {(1, 1): 1, (2, 2): 1, (1, 2): 1}
>>> dimod.qubo_energy(sample, Q, 0.5)
0.5
```

References

QUBO model on Wikipedia
Decorators

Decorators can be imported from the `dimod.decorators` namespace. For example:

```python
>>> from dimod.decorators import vartype_argument
```

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
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<tbody>
<tr>
<td><code>bqm_index_labels()</code></td>
<td>Decorator to convert a BQM to index-labels and relabel the sample set output.</td>
</tr>
<tr>
<td><code>bqm_index_labelled_input(...)</code></td>
<td>Returns a decorator that ensures BQM variable labeling and specified sample_like inputs are index labeled and consistent.</td>
</tr>
<tr>
<td><code>bqm_structured()</code></td>
<td>Decorator to raise an error if the given BQM does not match the sampler’s structure.</td>
</tr>
<tr>
<td><code>graph_argument(*arg_names, **options)</code></td>
<td>Decorator to coerce given graph arguments into a consistent form.</td>
</tr>
<tr>
<td><code>vartype_argument(*arg_names)</code></td>
<td>Ensures the wrapped function receives valid vartype argument(s).</td>
</tr>
</tbody>
</table>

**dimod.decorators.bqm_index_labels**

`bqm_index_labels(f)`

Decorator to convert a BQM to index-labels and relabel the sample set output.

Designed to be applied to `Sampler.sample()`. Expects the wrapped function or method to accept a `BinaryQuadraticModel` as the second input and to return a `SampleSet`.

**dimod.decorators.bqm_index_labelled_input**

`bqm_index_labelled_input(var_labels_arg_name, samples_arg_names)`

Returns a decorator that ensures BQM variable labeling and specified sample_like inputs are index labeled and consistent.

Parameters

- **var_labels_arg_name (str)** – Expected name of the argument used to pass in an index labeling for the binary quadratic model (BQM).
- **samples_arg_names (list[str])** – Expected names of sample_like inputs that should be indexed by the labels passed to the `var_labels_arg_name` argument. ‘samples_like’ is an extension of NumPy’s `array_like`.

Returns  Function decorator.

**dimod.decorators.bqm_structured**

`bqm_structured(f)`

Decorator to raise an error if the given BQM does not match the sampler’s structure.

Designed to be applied to `Sampler.sample()`. Expects the wrapped function or method to accept a `BinaryQuadraticModel` as the second input and for the `Sampler` to also be `Structured`. 

dimod.decorators.graph_argument

dimod.decorators.graph_argument(*arg_names, **options)
Decorator to coerce given graph arguments into a consistent form.

The wrapped function accepts either an integer \( n \), interpreted as a complete graph of size \( n \), a nodes/edges pair, a sequence of edges, or a NetworkX graph. The argument is converted into a nodes/edges 2-tuple.

Parameters

- \*arg_names (optional, default='G') – Names of the arguments for input graphs.
- allow_None (bool, optional, default=False) – If True, None can be passed through as an input graph.

dimod.decorators.vartype_argument

dimod.decorators.vartype_argument(*arg_names)
Ensures the wrapped function receives valid vartype argument(s).

One or more argument names can be specified as a list of string arguments.

Parameters

- *arg_names (list[str], argument names, optional, default='vartype') – Names of the constrained arguments in decorated function.

Returns
Function decorator.

Examples

```python
>>> from dimod.decorators import vartype_argument

>>> @vartype_argument()  
... def f(x, vartype):
...     print(vartype)
... 
>>> f(1, 'SPIN')
Vartype.SPIN
>>> f(1, vartype='SPIN')
Vartype.SPIN

>>> @vartype_argument('y')
... def f(x, y):
...     print(y)
... 
>>> f(1, 'SPIN')
Vartype.SPIN
>>> f(1, y='SPIN')
Vartype.SPIN

>>> @vartype_argument('z')
... def f(x, **kwargs):
...     print(kwargs['z'])
... 
>>> f(1, z='SPIN')
Vartype.SPIN
```
Note: The decorated function can explicitly list (name) vartype arguments constrained by `vartype_argument()` or it can use a keyword arguments `dict`.

See also:

`as_vartype()`

Graph-like

```python
class child_structure_dfs(sampler[, seen])
    Return the structure of a composed sampler using a depth-first search on its children.

dimod.utilities.child_structure_dfs
```

**child_structure_dfs** *(sampler, seen=None)*

Return the structure of a composed sampler using a depth-first search on its children.

**Parameters**

- **sampler** *(Sampler)* – Structured or composed sampler with at least one structured child.
- **seen** *(set, optional, default=False)* – IDs of already checked child samplers.

**Returns**

A named tuple of the form `Structure(nodelist, edgelist, adjacency)`, where the 3-tuple values are the `Structured.nodelist`, `Structured.edgelist` and `Structured.adjacency` attributes of the first structured sampler found.

**Return type** `namedtup`le

**Raises** `ValueError` – If no structured sampler is found.

**Examples:**

```python
>>> import dimod
>>> sampler = dimod.TrackingComposite(
    ...     dimod.StructureComposite(
    ...         dimod.ExactSolver(), [0, 1], [(0, 1)]))
>>> print(dimod.child_structure_dfs(sampler).nodelist)
[0, 1]
```

Serialization

**JSON**

JSON-encoding of dimod objects.

**Examples**

```python
>>> import json
>>> from dimod.serialization.json import DimodEncoder, DimodDecoder
    ...
```

(continues on next page)
```python
>>> bqm = dimod.BinaryQuadraticModel.from_ising({}, {('a', 'b'): -1})
>>> s = json.dumps(bqm, cls=DimodEncoder)
>>> new = json.loads(s, cls=DimodDecoder)
>>> bqm == new
True
```

```python
>>> import json
>>> from dimod.serialization.json import DimodEncoder, DimodDecoder
...  
>>> sampleset = dimod.SampleSet.from_samples({'a': -1, 'b': 1}, dimod.SPIN, energy=5)
>>> s = json.dumps(sampleset, cls=DimodEncoder)
>>> new = json.loads(s, cls=DimodDecoder)
>>> sampleset == new
True
```

```python
>>> import json
>>> from dimod.serialization.json import DimodEncoder, DimodDecoder
...

>>> # now inside a list
>>> s = json.dumps([sampleset, bqm], cls=DimodEncoder)
>>> new = json.loads(s, cls=DimodDecoder)
>>> new == [sampleset, bqm]
True
```

```python
class DimodEncoder(*, skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True,
sort_keys=False, indent=None, separators=None, default=None)
```

Subclass the JSONEncoder for dimod objects.

```python
class DimodDecoder(*args, **kwargs)
```

Subclass the JSONDecoder for dimod objects.

Uses `dimod_object_hook()`.

Functions

```python
dimod_object_hook(obj) JSON-decoding for dimod objects.
```

```python
dimod.serialization.json.dimod_object_hook
```

```python
dimod_object_hook(obj) JSON-decoding for dimod objects.
```

See also:

`json.JSONDecoder` for using custom decoders.

Testing

The testing subpackage contains functions for verifying and testing dimod objects. Testing objects/functions can be imported from the `dimod.testing` namespace. For example:

```python
>>> from dimod.testing import assert_sampler_api
```
API Asserts

<table>
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<td><code>assert_composite_api(composed_sampler)</code></td>
<td>Assert that an instantiated composed sampler exposes correct composite properties and methods.</td>
</tr>
<tr>
<td><code>assert_sampler_api(sampler)</code></td>
<td>Assert that an instantiated sampler exposes correct properties and methods.</td>
</tr>
<tr>
<td><code>assert_structured_api(sampler)</code></td>
<td>Assert that an instantiated structured sampler exposes correct composite properties and methods.</td>
</tr>
</tbody>
</table>

### `dimod.testing.asserts.assert_composite_api`

**assert_composite_api**(composed_sampler)

Assert that an instantiated composed sampler exposes correct composite properties and methods.

**Parameters**

- `sampler` (**Composite**) – User-made dimod composed sampler.

**Raises**

- `AssertionError` – If the given sampler does not match the composite API.

**See also:**

- `Composite` for the abstract base class that defines the composite API.
- `assert_sampler_api` to assert that the composed sampler matches the sampler API.

### `dimod.testing.asserts.assert_sampler_api`

**assert_sampler_api**(sampler)

Assert that an instantiated sampler exposes correct properties and methods.

**Parameters**

- `sampler` (**Sampler**) – User-made dimod sampler.

**Raises**

- `AssertionError` – If the given sampler does not match the sampler API.

**See also:**

- `Sampler` for the abstract base class that defines the sampler API.

### `dimod.testing.asserts.assert_structured_api`

**assert_structured_api**(sampler)

Assert that an instantiated structured sampler exposes correct composite properties and methods.

**Parameters**

- `sampler` (**Structured**) – User-made dimod structured sampler.

**Raises**

- `AssertionError` – If the given sampler does not match the structured API.

**See also:**

- `Structured` for the abstract base class that defines the structured API.
- `assert_sampler_api` to assert that the structured sampler matches the sampler API.

### Correctness Asserts
dimod Documentation, Release 0.8.21

**dimod.testing.asserts.assert_bqm_almost_equal**

**assert_bqm_almost_equal** *(actual, desired, places=7, ignore_zero_interactions=False)*

Test if two binary quadratic models have almost equal biases.

**Parameters**

- **actual** *(BinaryQuadraticModel)* – First binary quadratic model.
- **desired** *(BinaryQuadraticModel)* – Second binary quadratic model.
- **places** *(int, optional, default=7)* – Bias equality is computed as \( \text{round}(b0 - b1, \text{places}) == 0 \).
- **ignore_zero_interactions** *(bool, optional, default=False)* – If true, interactions with 0 bias are ignored.

**dimod.testing.asserts.assert_response_energies**

**assert_response_energies** *(response, bqm, precision=7)*

Assert that each sample in the given response has the correct energy.

**Parameters**

- **response** *(SampleSet)* – Response as returned by a dimod sampler.
- **bqm** *(BinaryQuadraticModel)* – Binary quadratic model (BQM) used to generate the samples.
- **precision** *(int, optional, default=7)* – Equality of energy is tested by calculating the difference between the response’s sample energy and that returned by BQM’s energy(), rounding to the closest multiple of 10 to the power of minus precision.

**Raises**

- **AssertionError** – If any of the samples in the response do not match their associated energy.

**See also:**

assert_sampleset_energies()

**dimod.testing.asserts.assert_sampleset_energies**

**assert_sampleset_energies** *(sampleset, bqm, precision=7)*

Assert that each sample in the given sample set has the correct energy.

**Parameters**

- **sampleset** *(SampleSet)* – Sample set as returned by a dimod sampler.
• `bqm(BinaryQuadraticModel/BinaryPolynomial)` – The binary quadratic model (BQM) or binary polynomial used to generate the samples.

• `precision(int, optional, default=7)` – Equality of energy is tested by calculating the difference between the response’s sample energy and that returned by BQM’s `energy()`, rounding to the closest multiple of 10 to the power of minus `precision`.

Raises

• `AssertionError` – If any of the samples in the sample set do not match
  • their associated energy.

Examples

```python
>>> import dimod.testing
... >>> sampler = dimod.ExactSolver()
>>> bqm = dimod.BinaryQuadraticModel.from_ising({}, {(0, 1): -1})
>>> sampleset = sampler.sample(bqm)
>>> dimod.testing.assert_response_energies(sampleset, bqm)
```

Vartype Conversion

<table>
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<tr>
<td><code>ising_to_qubo(h, J[, offset])</code></td>
<td>Convert an Ising problem to a QUBO problem.</td>
</tr>
<tr>
<td><code>qubo_to_ising(Q[, offset])</code></td>
<td>Convert a QUBO problem to an Ising problem.</td>
</tr>
</tbody>
</table>

**dimod.utilities.ising_to_qubo**

`ising_to_qubo(h, J[, offset=0.0])`

Convert an Ising problem to a QUBO problem.

Map an Ising model defined on spins (variables with {-1, +1} values) to quadratic unconstrained binary optimization (QUBO) formulation $x'Qx$ defined over binary variables (0 or 1 values), where the linear term is contained along the diagonal of $Q$. Return matrix $Q$ that defines the model as well as the offset in energy between the two problem formulations:

$$s'Js + h's = offset + x'Qx$$

See `qubo_to_ising()` for the inverse function.

Parameters

• `h(dict[variable, bias])` – Linear biases as a dict of the form `{v: bias, ...}`, where keys are variables of the model and values are biases.

• `J(dict[(variable, variable), bias])` – Quadratic biases as a dict of the form `{(u, v): bias, ...}`, where keys are 2-tuples of variables of the model and values are quadratic biases associated with the pair of variables (the interaction).

• `offset(numeric, optional, default=0)` – Constant offset to be applied to the energy. Default 0.

Returns

A 2-tuple containing:
dict: QUBO coefficients.
float: New energy offset.

Return type  (dict, float)

Examples

This example converts an Ising problem of two variables that have positive biases of value 1 and are positively coupled with an interaction of value 1 to a QUBO problem.

```python
>>> import dimod

>>> h = {1: 1, 2: 1}

>>> J = {(1, 2): 1}

>>> dimod.ising_to_qubo(h, J, 0.5)  # doctest: +SKIP
({(1, 1): 0.0, (1, 2): 4.0, (2, 2): 0.0}, -0.5)
```

dimod.utilities.qubo_to_ising

**qubo_to_ising** *(Q, offset=0.0)*

Convert a QUBO problem to an Ising problem.

Map a quadratic unconstrained binary optimization (QUBO) problem \(x'Qx\) defined over binary variables (0 or 1 values), where the linear term is contained along the diagonal of \(Q\), to an Ising model defined on spins (variables with \{-1, +1\} values). Return \(h\) and \(J\) that define the Ising model as well as the offset in energy between the two problem formulations:

\[
x'Qx = offset + s'Js + h's
\]

See **ising_to_qubo()** for the inverse function.

Parameters

- \(Q\) *(dict[(variable, variable), coefficient]*) – QUBO coefficients in a dict of form \{(u, v): coefficient, ...\}, where keys are 2-tuples of variables of the model and values are biases associated with the pair of variables. Tuples \((u, v)\) represent interactions and \((v, v)\) linear biases.
- \(offset\) *(numeric, optional, default=0.0)* – Constant offset to be applied to the energy. Default 0.

Returns

A 3-tuple containing:
- float: New energy offset.

Return type  (dict, dict, float)

Examples

This example converts a QUBO problem of two variables that have positive biases of value 1 and are positively coupled with an interaction of value 1 to an Ising problem.
```python
>>> import dimod

>>> Q = {(1, 1): 1, (2, 2): 1, (1, 2): 1}

>>> dimod.qubo_to_ising(Q, 0.5)  
    # doctest: +SKIP

    ({1: 0.75, 2: 0.75}, {(1, 2): 0.25}, 1.75)
```

## 2.2.6 Vartype

Enumeration of valid variable types for binary quadratic models.

### Examples

`Vartype` is an `Enum`. Each vartype has a value and a name.

```python
>>> vartype = dimod.SPIN
>>> vartype.name
'SPIN'
>>> vartype.value == {-1, +1}
True

>>> vartype = dimod.BINARY
>>> vartype.name
'BINARY'
>>> vartype.value == {0, 1}
True
```

The `as_vartype()` function allows the user to provide several convenient forms.

```python
>>> from dimod import as_vartype

>>> as_vartype(dimod.SPIN)  is  dimod.SPIN
True
>>> as_vartype('SPIN')  is  dimod.SPIN
True
>>> as_vartype((-1, 1))  is  dimod.SPIN
True

>>> as_vartype(dimod.BINARY)  is  dimod.BINARY
True
>>> as_vartype('BINARY')  is  dimod.BINARY
True
>>> as_vartype({0, 1})  is  dimod.BINARY
True
```

### class Vartype

An `Enum` over the types of variables for the binary quadratic model.

**SPIN**

Vartype for spin-valued models; variables of the model are either -1 or 1.

Type `Vartype`

**BINARY**

Vartype for binary models; variables of the model are either 0 or 1.

Type `Vartype`
as_vartype(vartype)

Cast various inputs to a valid vartype object.

Parameters

    vartype (Vartype/str/set) – Variable type. Accepted input values:

    • Vartype.SPIN, 'SPIN', {-1, 1}
    • Vartype.BINARY, 'BINARY', {0, 1}

Returns

    Either Vartype.SPIN or Vartype.BINARY.

Return type

    Vartype

See also:

    vartype_argument()

2.2.7 Exceptions

exception BinaryQuadraticModelSizeError

Raised when the binary quadratic model has too many variables

exception BinaryQuadraticModelStructureError

Raised when the binary quadratic model does not fit the sampler

exception BinaryQuadraticModelValueError

Raised when a sampler cannot handle a specified binary quadratic model

exception InvalidComposition

Raised for compositions of samplers that are invalid

exception InvalidSampler

Raised when trying to use the specified sampler as a sampler

exception MappingError

Raised when mapping causes conflicting values in samples

exception WriteableError

Raised when trying to modify an immutable object.

2.3 Bibliography

2.4 Installation

Compatible with Python 2 and 3:

```
ip install dimod
```

To install with optional components:

```
ip install dimod[all]
```

To install from source:

```
ip install -r requirements.txt
python setup.py install
```
Note that for an installation from source some functionality requires that your system have Boost C++ libraries installed.

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CHAPTER 3

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