

HNCO

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Chapter 1

Namespace Index

1.1 Namespace List

Here is a list of all documented namespaces with brief descriptions:

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Chapter 2

Hierarchical Index

2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

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Class Index

3.1 Class List

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Chapter 4

Namespace Documentation

4.1 hnco Namespace Reference

top-level HNCO namespace

Namespaces

- [algorithm](#)
Algorithms.
- [exception](#)
Exceptions.
- [function](#)
Functions to be maximized.
- [neighborhood](#)
Neighborhoods for local search.
- [random](#)
Pseudo random numbers.

Classes

- class [AffineMap](#)
Affine map.
- class [HypercubeIterator](#)
Hypercube iterator.
- class [Iterator](#)
[Iterator](#) over bit vectors.
- class [LinearMap](#)
Linear map.
- class [Map](#)
Map.
- class [MapComposition](#)
Map composition.
- class [Permutation](#)
Permutation.
- class [Translation](#)
Translation.

Types and functions related to bit matrices

- typedef std::vector< [bit_vector_t](#) > [bit_matrix_t](#)
Bit matrix.
- void [bm_display](#) (const [bit_matrix_t](#) &M, std::ostream &stream)
Display bit matrix.
- bool [bm_is_valid](#) (const [bit_matrix_t](#) &M)
Check whether a bit matrix is valid.
- size_t [bm_num_rows](#) (const [bit_matrix_t](#) &M)
Number of rows.
- size_t [bm_num_columns](#) (const [bit_matrix_t](#) &M)
Number of columns.
- bool [bm_is_square](#) (const [bit_matrix_t](#) &M)
Check whether the matrix is a square matrix.
- bool [bm_is_identity](#) (const [bit_matrix_t](#) &M)
Check whether the matrix is the identity matrix.
- bool [bm_is_upper_triangular](#) (const [bit_matrix_t](#) &M)
Check whether the matrix is upper triangular.
- void [bm_resize](#) ([bit_matrix_t](#) &M, std::size_t num_rows, std::size_t num_columns)
Resize a bit matrix.
- void [bm_resize](#) ([bit_matrix_t](#) &M, std::size_t num_rows)
Resize a bit matrix and make it a square matrix.
- void [bm_clear](#) ([bit_matrix_t](#) &M)
Clear bit matrix.
- void [bm_identity](#) ([bit_matrix_t](#) &M)
Set the matrix to the identity matrix.
- void [bm_random](#) ([bit_matrix_t](#) &M)
Sample a random bit matrix.
- void [bm_swap_rows](#) ([bit_matrix_t](#) &M, std::size_t i, std::size_t j)
Swap two rows.
- void [bm_add_rows](#) ([bit_matrix_t](#) &M, std::size_t i, std::size_t j)
Add two rows.
- bool [bm_solve](#) ([bit_matrix_t](#) &A, [bit_vector_t](#) &b)
Solve a linear system.
- bool [bm_solve_upper_triangular](#) ([bit_matrix_t](#) &A, [bit_vector_t](#) &b)
Solve a linear system in upper triangular form.
- bool [bm_invert](#) ([bit_matrix_t](#) &M, [bit_matrix_t](#) &N)
Invert a bit matrix.
- void [bm_multiply](#) (const [bit_matrix_t](#) &M, const [bit_vector_t](#) &x, [bit_vector_t](#) &y)
Multiply a bit matrix and a bit vector.
- void [bm_transpose](#) (const [bit_matrix_t](#) &M, [bit_matrix_t](#) &N)
Transpose.

Types and functions related to bit vectors

- typedef char [bit_t](#)
Bit.
- typedef std::vector< [bit_t](#) > [bit_vector_t](#)
Bit vector.
- typedef std::pair< [bit_vector_t](#), double > [point_value_t](#)

- Type to represent point value pairs.*
- [bit_t bit_flip](#) ([bit_t](#) b)
Flip bit.
- void [bv_display](#) (const [bit_vector_t](#) &v, std::ostream &stream)
Display bit vector.
- bool [bv_is_valid](#) (const [bit_vector_t](#) &x)
Check whether the bit vector is valid.
- bool [bv_is_zero](#) (const [bit_vector_t](#) &x)
Check whether the bit vector is zero.
- int [bv_hamming_weight](#) (const [bit_vector_t](#) &x)
Hamming weight.
- int [bv_hamming_distance](#) (const [bit_vector_t](#) &x, const [bit_vector_t](#) &y)
Hamming distance between two bit vectors.
- [bit_t bv_dot_product](#) (const [bit_vector_t](#) &x, const [bit_vector_t](#) &y)
Dot product.
- void [bv_clear](#) ([bit_vector_t](#) &x)
Clear bit vector.
- void [bv_flip](#) ([bit_vector_t](#) &x, std::size_t i)
Flip a single bit.
- void [bv_flip](#) ([bit_vector_t](#) &x, const [bit_vector_t](#) &mask)
Flip many bits.
- void [bv_random](#) ([bit_vector_t](#) &x)
Sample a random bit vector.
- void [bv_random](#) ([bit_vector_t](#) &x, int k)
Sample a random bit vector with given Hamming weight.
- void [bv_add](#) (const [bit_vector_t](#) &src, [bit_vector_t](#) &dest)
Add two bit vectors.
- void [bv_add](#) (const [bit_vector_t](#) &x, const [bit_vector_t](#) &y, [bit_vector_t](#) &dest)
Add two bit vectors.

Types and functions related to permutations

- typedef std::vector< std::size_t > [permutation_t](#)
Permutation type.
- bool [perm_is_valid](#) (const [permutation_t](#) &permutation)
Check that a vector represents a permutation.
- void [perm_random](#) ([permutation_t](#) &s)
Sample a random permutation.

Types and functions related to sparse bit matrices

- typedef std::vector< [sparse_bit_vector_t](#) > [sparse_bit_matrix_t](#)
Sparse bit matrix.
- void [sbm_display](#) (const [sparse_bit_matrix_t](#) &sbm, std::ostream &stream)
Display sparse bit matrix.
- void [bm_to_sbm](#) (const [bit_matrix_t](#) &bm, [sparse_bit_matrix_t](#) &sbm)
Convert a bit matrix to a sparse bit matrix.
- void [sbm_multiply](#) (const [sparse_bit_matrix_t](#) &M, const [bit_vector_t](#) &x, [bit_vector_t](#) &y)
Multiply a sparse bit matrix and a bit vector.

Types and functions related to sparse bit vectors

- `typedef std::vector< std::size_t > sparse_bit_vector_t`
Sparse bit vector.
- `void bv_flip (bit_vector_t &x, const sparse_bit_vector_t &sbv)`
Flip many bits.
- `void sbv_display (const sparse_bit_vector_t &v, std::ostream &stream)`
Display sparse bit vector.
- `void bv_to_sbv (const bit_vector_t &bv, sparse_bit_vector_t &sbv)`
Convert a bit vector to a sparse bit vector.

4.1.1 Detailed Description

top-level HNCO namespace

4.1.2 Typedef Documentation

4.1.2.1 bit_t

```
typedef char bit_t
```

Bit.

A single bit is represented by a char and the values 0 for false and 1 for true.

Definition at line 52 of file bit-vector.hh.

4.1.2.2 sparse_bit_matrix_t

```
typedef std::vector<sparse_bit_vector_t> sparse_bit_matrix_t
```

Sparse bit matrix.

A sparse bit matrix is represented as an array of sparse bit vectors. It knows its number of row, not its number of columns.

Definition at line 45 of file sparse-bit-matrix.hh.

4.1.2.3 sparse_bit_vector_t

```
typedef std::vector<std::size_t> sparse_bit_vector_t
```

Sparse bit vector.

A sparse bit vector is represented as an array containing the indices of its non-zero components. The indices must be sorted in ascending order.

A sparse bit vector does not know the dimension of the space it belongs to.

Definition at line 47 of file sparse-bit-vector.hh.

4.1.3 Function Documentation

4.1.3.1 bm_add_rows()

```
void bm_add_rows (
    bit_matrix_t & M,
    std::size_t i,
    std::size_t j )
```

Add two rows.

Row i is added to row j.

Definition at line 94 of file bit-matrix.cc.

4.1.3.2 bm_identity()

```
void bm_identity (
    bit_matrix_t & M )
```

Set the matrix to the identity matrix.

Precondition

bm_is_square(M)

Definition at line 29 of file bit-matrix.cc.

4.1.3.3 bm_invert()

```
bool bm_invert (
    bit_matrix_t & M,
    bit_matrix_t & N )
```

Invert a bit matrix.

Parameters

M	input matrix
N	inverse matrix

Precondition

`bm_is_square(M)`
`bm_is_square(N)`

Returns

true if M is invertible

Warning

M is modified by the function. Provided that M is invertible, after returning from the function, M is the identity matrix and N is the computed inverse matrix.

Definition at line 153 of file bit-matrix.cc.

4.1.3.4 `bm_multiply()`

```
void bm_multiply (
    const bit_matrix_t & M,
    const bit_vector_t & x,
    bit_vector_t & y )
```

Multiply a bit matrix and a bit vector.

The result is $y = Mx$.

Definition at line 195 of file bit-matrix.cc.

4.1.3.5 `bm_solve()`

```
bool bm_solve (
    bit_matrix_t & A,
    bit_vector_t & b )
```

Solve a linear system.

Solve the linear equation $Ax = b$.

Parameters

A	Matrix
b	Right hand side

Precondition

```
bm_is_square(A)
bm_num_rows(A) == b.size()
```

Returns

true if the system has a unique solution

Warning

Both A and b are modified by the function. Provided that A is invertible, after returning from the function, A is the identity matrix and b is the unique solution to the linear equation.

Definition at line 103 of file bit-matrix.cc.

4.1.3.6 `bm_solve_upper_triangular()`

```
bool bm_solve_upper_triangular (
    bit_matrix_t & A,
    bit_vector_t & b )
```

Solve a linear system in upper triangular form.

Solve the linear equation $Ax = b$.

Parameters

A	Upper triangular matrix
b	Right hand side

Precondition

```
bm_is_square(A)
bm_num_rows(A) == b.size()
bm_is_upper_triangular(A)
```

Returns

true if the system has a unique solution

Warning

Both A and b are modified by the function. Provided that A is invertible, after returning from the function, A is the identity matrix and b is the unique solution to the linear equation.

Definition at line 134 of file bit-matrix.cc.

4.1.3.7 sbm_multiply()

```
void hnco::sbm_multiply (
    const sparse_bit_matrix_t & M,
    const bit_vector_t & x,
    bit_vector_t & y ) [inline]
```

Multiply a sparse bit matrix and a bit vector.

The result is $y = Mx$.

Definition at line 68 of file sparse-bit-matrix.hh.

4.2 hnco::algorithm Namespace Reference

Algorithms.

Namespaces

- [bm_pbil](#)
Boltzmann machine PBIL.
- [hea](#)
Herding evolutionary algorithm.

Classes

- class [Algorithm](#)
Abstract search algorithm.
- class [BiasedCrossover](#)
Biased crossover.
- class [CompactGa](#)
Compact genetic algorithm.
- class [CompleteSearch](#)
Complete search.
- class [Crossover](#)
Crossover.
- class [GeneticAlgorithm](#)
Genetic algorithm.
- class [IterativeAlgorithm](#)
Iterative search.

- class [Mmas](#)
Max-min ant system.
- class [MuCommaLambdaEa](#)
(mu, lambda) EA.
- class [MuPlusLambdaEa](#)
(mu+lambda) EA.
- class [NpsPbil](#)
Population-based incremental learning with negative and positive selection.
- class [OnePlusLambdaCommaLambdaGa](#)
(1+(lambda, lambda)) genetic algorithm.
- class [OnePlusOneEa](#)
(1+1) EA.
- class [Pbil](#)
Population-based incremental learning.
- class [Population](#)
Population.
- class [PvAlgorithm](#)
Probability vector algorithm.
- class [RandomLocalSearch](#)
Random local search.
- class [RandomSearch](#)
Random search.
- class [Restart](#)
Restart.
- class [SimulatedAnnealing](#)
Simulated annealing.
- class [SteepestAscentHillClimbing](#)
Steepest ascent hill climbing.
- class [TournamentSelection](#)
Population with tournament selection.
- class [Umda](#)
Univariate marginal distribution algorithm.
- class [UniformCrossover](#)
Uniform crossover.

Functions

- template<class T >
bool [matrix_is_symmetric](#) (const std::vector< std::vector< T > > &A)
Check for symmetric matrix.
- template<class T >
bool [matrix_has_diagonal](#) (const std::vector< std::vector< T > > &A, T x)
Check for diagonal elements.
- template<class T >
bool [matrix_has_range](#) (const std::vector< std::vector< T > > &A, T inf, T sup)
Check for element range.
- template<class T >
bool [matrix_has_dominant_diagonal](#) (const std::vector< std::vector< T > > &A)
Check for element range.
- template<class T >
T [square](#) (T x)
Generic square function.
- double [logistic](#) (double x)
Logistic function (sigmoid)

Type and functions related to probability vectors

- typedef std::vector< double > [pv_t](#)
Probability vector type.
- double [pv_entropy](#) (const [pv_t](#) &pv)
Entropy of a probability vector.
- void [pv_sample](#) (const [pv_t](#) &pv, [bit_vector_t](#) &x)
Sample a bit vector.
- void [pv_uniform](#) ([pv_t](#) &pv)
Probability vector of the uniform distribution.
- void [pv_init](#) ([pv_t](#) &pv)
Initialize.
- void [pv_add](#) ([pv_t](#) &pv, const [bit_vector_t](#) &x)
Accumulate a bit vector.
- void [pv_add](#) ([pv_t](#) &pv, const [bit_vector_t](#) &x, double weight)
Accumulate a bit vector.
- void [pv_average](#) ([pv_t](#) &pv, int count)
Average.
- void [pv_update](#) ([pv_t](#) &pv, double rate, const [bit_vector_t](#) &x)
Update a probability vector toward a bit vector.
- void [pv_update](#) ([pv_t](#) &pv, double rate, const std::vector< double > &x)
Update a probability vector toward a probability vector.
- void [pv_update](#) ([pv_t](#) &pv, double rate, const std::vector< double > &x, const std::vector< double > &y)
Update a probability vector toward a probability vector and away from another one.
- void [pv_bound](#) ([pv_t](#) &pv, double lower_bound, double upper_bound)
Bound the components of a probability vector.

4.2.1 Detailed Description

Algorithms.

4.3 hnco::algorithm::bm_pbil Namespace Reference

Boltzmann machine PBIL.

Classes

- class [BmPbil](#)
Boltzmann machine PBIL.
- class [Model](#)
Model of a Boltzmann machine.
- class [ModelParameters](#)
Parameters of a Boltzmann machine.

4.3.1 Detailed Description

Boltzmann machine PBIL.

4.4 `hnco::algorithm::hea` Namespace Reference

Herding evolutionary algorithm.

Classes

- class [BinaryHerding](#)
Herding with binary variables.
- struct [BinaryMoment](#)
Moment for binary variables.
- class [Hea](#)
Herding evolutionary algorithm.
- class [SpinHerding](#)
Herding with spin variables.
- struct [SpinMoment](#)
Moment for spin variables.

4.4.1 Detailed Description

Herding evolutionary algorithm.

4.5 `hnco::exception` Namespace Reference

Exceptions.

Classes

- class [Error](#)
Error.
- class [Exception](#)
Basic exception.
- class [LastEvaluation](#)
Last evaluation.
- class [LocalMaximum](#)
Local maximum.
- class [MaximumReached](#)
Maximum reached.
- class [PointValueException](#)
Point-value exception.
- class [TargetReached](#)
target reached

4.5.1 Detailed Description

Exceptions.

4.6 hnco::function Namespace Reference

Functions to be maximized.

Classes

- class [AdditiveGaussianNoise](#)
Additive Gaussian Noise.
- class [Cache](#)
Cache.
- class [CallCounter](#)
Call counter.
- class [DeceptiveJump](#)
Deceptive jump.
- class [EqualProducts](#)
Equal products.
- class [Factorization](#)
Factorization.
- class [FourPeaks](#)
Four Peaks.
- class [Function](#)
Function.
- class [FunctionController](#)
Function controller.
- class [FunctionDecorator](#)
Function decorator.
- class [FunctionMapComposition](#)
Composition of a function and a map.
- class [FunctionModifier](#)
Function modifier.
- class [FunctionPlugin](#)
Function plugin.
- class [Hiff](#)
Hierarchical if and only if.
- class [Jump](#)
Jump.
- class [Labs](#)
Low autocorrelation binary sequences.
- class [LeadingOnes](#)
Leading ones.
- class [LinearFunction](#)
Linear function.
- class [LongPath](#)
Long path.
- class [MaxSat](#)
MAX-SAT.
- class [Needle](#)
Needle in a haystack.
- class [Negation](#)

- *Negation.*
- class [NkLandscape](#)
NK landscape.
- class [OnBudgetFunction](#)
CallCounter with a limited number of evaluations.
- class [OneMax](#)
OneMax.
- class [Plateau](#)
Plateau.
- class [PriorNoise](#)
Prior noise.
- class [ProgressTracker](#)
ProgressTracker.
- class [Qubo](#)
Quadratic unconstrained binary optimization.
- class [Ridge](#)
Ridge.
- class [SinusSummationCancellation](#)
Summation cancellation with sinus.
- class [SixPeaks](#)
Six Peaks.
- class [StopOnMaximum](#)
Stop on maximum.
- class [StopOnTarget](#)
Stop on target.
- class [SummationCancellation](#)
Summation cancellation.
- class [Trap](#)
Trap.
- class [WalshExpansion](#)
Walsh expansion.
- class [WalshExpansion1](#)
Walsh expansion of degree 1.
- class [WalshExpansion2](#)
Walsh expansion of degree 2.

Functions

- `std::ostream & operator<< (std::ostream &stream, const ProgressTracker::Event &event)`
Insert formatted output.

4.6.1 Detailed Description

Functions to be maximized.

4.7 hngo::neighborhood Namespace Reference

Neighborhoods for local search.

Classes

- class [BernoulliProcess](#)
Bernoulli process.
- class [HammingBall](#)
Hamming ball.
- class [HammingBallIterator](#)
Hamming ball neighborhood iterator.
- class [HammingSphere](#)
Hamming sphere.
- class [MultiBitFlip](#)
Multi bit flip.
- class [Neighborhood](#)
Neighborhood.
- class [NeighborhoodIterator](#)
Neighborhood iterator.
- class [SingleBitFlip](#)
One bit neighborhood.
- class [SingleBitFlipIterator](#)
Single bit flip neighborhood iterator.

4.7.1 Detailed Description

Neighborhoods for local search.

There are two unrelated kinds of neighborhoods, those for random local search and those for exhaustive local search.

4.8 `hnco::random` Namespace Reference

Pseudo random numbers.

Classes

- struct [Random](#)
Random numbers.

4.8.1 Detailed Description

Pseudo random numbers.

Chapter 5

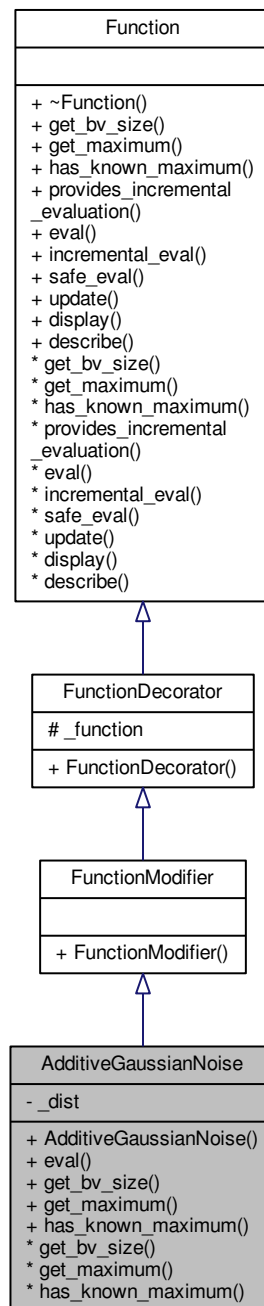
Class Documentation

5.1 AdditiveGaussianNoise Class Reference

Additive Gaussian Noise.

```
#include <hnco/functions/decorators/function-modifier.hh>
```

Inheritance diagram for AdditiveGaussianNoise:



Public Member Functions

- [AdditiveGaussianNoise](#) ([Function](#) *function, double stddev)
Constructor.
- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

Information about the function

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [get_maximum](#) ()
Get the global maximum.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.

Private Attributes

- `std::normal_distribution< double >` [_dist](#)
Normal distribution.

Additional Inherited Members

5.1.1 Detailed Description

Additive Gaussian Noise.

Definition at line 166 of file `function-modifier.hh`.

5.1.2 Member Function Documentation

5.1.2.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Exceptions

<i>Error</i>	
--------------	--

Reimplemented from [Function](#).

Definition at line 188 of file `function-modifier.hh`.

5.1.2.2 `has_known_maximum()`

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

false

Reimplemented from [Function](#).

Definition at line 192 of file function-modifier.hh.

The documentation for this class was generated from the following files:

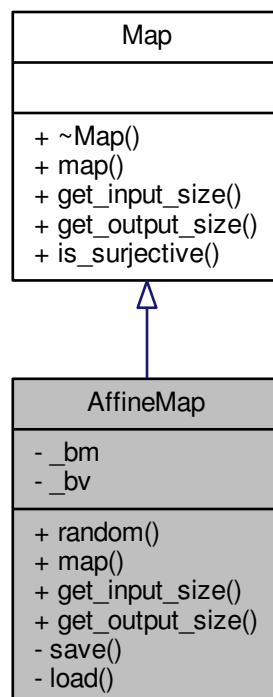
- lib/hnco/functions/decorators/function-modifier.hh
- lib/hnco/functions/decorators/function-modifier.cc

5.2 AffineMap Class Reference

Affine map.

```
#include <hnco/map.hh>
```

Inheritance diagram for AffineMap:



Public Member Functions

- void `random` (int n, int m)
Random instance.
- void `map` (const `bit_vector_t` &input, `bit_vector_t` &output)
Map.
- `size_t` `get_input_size` ()
Get input size.
- `size_t` `get_output_size` ()
Get output size.

Private Member Functions

- template<class Archive >
void `save` (Archive &ar, const unsigned int version) const
Save.
- template<class Archive >
void `load` (Archive &ar, const unsigned int version)
Load.

Private Attributes

- `bit_matrix_t` `_bm`
Bit matrix.
- `bit_vector_t` `_bv`
Translation vector.

Friends

- class `boost::serialization::access`

5.2.1 Detailed Description

Affine map.

An affine map f from Z_2^m to Z_2^n is defined by $f(x) = Ax + b$, where A is an $n \times m$ bit matrix and b is an n -dimensional bit vector.

Warning

The class does not reimplement the member function `is_surjective` hence a linear map is always considered not surjective.

Definition at line 258 of file `map.hh`.

The documentation for this class was generated from the following files:

- `lib/hnco/map.hh`
- `lib/hnco/map.cc`

Protected Member Functions

- void `random_solution` ()
Random solution.
- void `set_solution` (const `bit_vector_t` &x, double value)
Set solution.
- void `set_solution` (const `bit_vector_t` &x)
Set solution.
- void `update_solution` (const `bit_vector_t` &x, double value)
Update solution (strict)
- void `update_solution` (const `point_value_t` &pv)
Update solution (strict)
- void `update_solution` (const `bit_vector_t` &x)
Update solution (strict)

Protected Attributes

- `function::Function * _function`
Function.
- `std::vector< function::Function * > _functions`
Functions.
- `point_value_t _solution`
Solution.

5.3.1 Detailed Description

Abstract search algorithm.

All algorithms maximize some given function, sometimes called a fitness function or an objective function.

Definition at line 38 of file `algorithm.hh`.

5.3.2 Member Data Documentation

5.3.2.1 `_functions`

```
std::vector<function::Function *> _functions [protected]
```

Functions.

Each thread has its own function.

Definition at line 49 of file `algorithm.hh`.

The documentation for this class was generated from the following files:

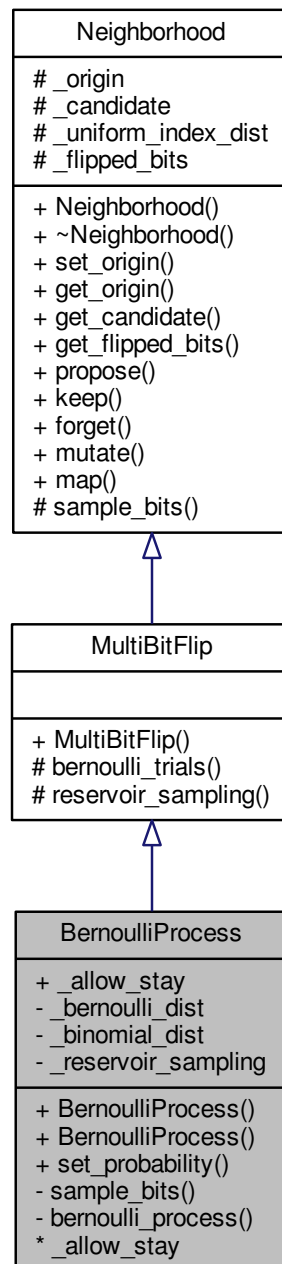
- `lib/hnco/algorithms/algorithm.hh`
- `lib/hnco/algorithms/algorithm.cc`

5.4 BernoulliProcess Class Reference

Bernoulli process.

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for BernoulliProcess:



Public Member Functions

- [BernoulliProcess](#) (int n)
Constructor.
- [BernoulliProcess](#) (int n, double p)
Constructor.
- void [set_probability](#) (double p)
Set probability.

Public Attributes

Parameters

- bool [_allow_stay](#) = false
Allow stay.

Private Member Functions

- void [sample_bits](#) ()
Sample bits.
- void [bernoulli_process](#) ()
Bernoulli process.

Private Attributes

- std::bernoulli_distribution [_bernoulli_dist](#)
Bernoulli distribution (biased coin)
- std::binomial_distribution< int > [_binomial_dist](#)
Binomial distribution.
- bool [_reservoir_sampling](#) = false
Reservoir sampling.

Additional Inherited Members

5.4.1 Detailed Description

Bernoulli process.

Each component of the origin bit vector is flipped with some fixed probability. If no component has been flipped at the end, the process is started all over again. Thus the number of flipped bits follows a pseudo binomial law.

Definition at line 220 of file neighborhood.hh.

5.4.2 Constructor & Destructor Documentation

5.4.2.1 BernoulliProcess() [1/2]

```
BernoulliProcess (
    int n ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
-----	---------------------

The Bernoulli probability is set to $1 / n$.

Definition at line 246 of file neighborhood.hh.

5.4.2.2 BernoulliProcess() [2/2]

```
BernoulliProcess (
    int n,
    double p ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
p	Bernoulli probability

Definition at line 256 of file neighborhood.hh.

5.4.3 Member Function Documentation**5.4.3.1 set_probability()**

```
void set_probability (
    double p ) [inline]
```

Set probability.

Sets `_reservoir_sampling` to true if $E(X) < \sqrt{n}$, where X is a random variable with a binomial distribution $B(n, p)$, that is if $np < \sqrt{n}$ or $p < 1 / \sqrt{n}$.

Definition at line 267 of file neighborhood.hh.

5.4.4 Member Data Documentation

5.4.4.1 `_allow_stay`

```
bool _allow_stay = false
```

Allow stay.

In case no mutation occurs allow the current bit vector to stay unchanged.

Definition at line 283 of file neighborhood.hh.

The documentation for this class was generated from the following files:

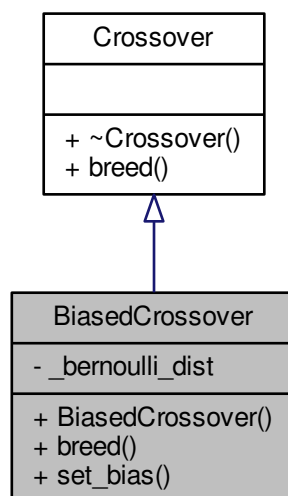
- lib/hnco/neighborhoods/neighborhood.hh
- lib/hnco/neighborhoods/neighborhood.cc

5.5 BiasedCrossover Class Reference

Biased crossover.

```
#include <hnco/algorithms/ea/crossover.hh>
```

Inheritance diagram for BiasedCrossover:



Public Member Functions

- [BiasedCrossover](#) ()
Constructor.
- void [breed](#) (const [bit_vector_t](#) &parent1, const [bit_vector_t](#) &parent2, [bit_vector_t](#) &offspring)
Breed.
- void [set_bias](#) (double b)
Set bias.

Private Attributes

- `std::bernoulli_distribution _bernoulli_dist`
Bernoulli distribution.

5.5.1 Detailed Description

Biased crossover.

Definition at line 75 of file `crossover.hh`.

5.5.2 Member Function Documentation

5.5.2.1 `breed()`

```
void breed (
    const bit_vector_t & parent1,
    const bit_vector_t & parent2,
    bit_vector_t & offspring ) [virtual]
```

Breed.

Each offspring's bit is copied from second parent with a fixed probability (the crossover bias), from first parent otherwise.

Parameters

<i>parent1</i>	First parent
<i>parent2</i>	Second parent
<i>offspring</i>	Offspring

Implements [Crossover](#).

Definition at line 45 of file `crossover.cc`.

The documentation for this class was generated from the following files:

- `lib/hnco/algorithms/ea/crossover.hh`
- `lib/hnco/algorithms/ea/crossover.cc`

5.6 BinaryHerding Class Reference

Herding with binary variables.

```
#include <hnco/algorithms/hea/herding-binary.hh>
```

Public Types

- enum { [DYNAMICS_MINIMIZE_NORM](#), [DYNAMICS_MAXIMIZE_INNER_PRODUCT](#) }

Public Member Functions

- [BinaryHerding](#) (int n)
Constructor.
- void [init](#) ()
Initialization.
- double [error](#) (const [BinaryMoment](#) &target)
Compute the error.
- double [delta](#) (const [BinaryMoment](#) &target)
Compute the norm of delta.
- void [sample](#) (const [BinaryMoment](#) &target, [bit_vector_t](#) &x)
Sample a bit vector.

Public Attributes

Parameters

- bool [_randomize_bit_order](#) = false
Randomize bit order.
- int [_dynamics](#) = [DYNAMICS_MINIMIZE_NORM](#)
Dynamics.
- double [_weight](#) = 1
Weight of second order moments.

Protected Member Functions

- void [compute_delta](#) (const [BinaryMoment](#) &target)
Compute delta.
- void [sample_minimize_norm](#) (const [BinaryMoment](#) &target, [bit_vector_t](#) &x)
Sample a bit vector.
- void [sample_maximize_inner_product](#) (const [BinaryMoment](#) &target, [bit_vector_t](#) &x)
Sample a bit vector.

Protected Attributes

- [BinaryMoment_count](#)
Counter moment.
- [BinaryMoment_delta](#)
Delta moment.
- [permutation_t_permutation](#)
Permutation.
- std::uniform_int_distribution< int > [_choose_bit](#)
Choose bit.
- int [_time](#)
Time.

5.6.1 Detailed Description

Herding with binary variables.

Definition at line 38 of file herding-binary.hh.

5.6.2 Member Enumeration Documentation

5.6.2.1 anonymous enum

anonymous enum

Enumerator

DYNAMICS_MINIMIZE_NORM	Dynamics defined as minimization of a norm.
DYNAMICS_MAXIMIZE_INNER_PRODUCT	Dynamics defined as maximization of an inner product.

Definition at line 69 of file herding-binary.hh.

The documentation for this class was generated from the following files:

- lib/hnco/algorithms/hea/herding-binary.hh
- lib/hnco/algorithms/hea/herding-binary.cc

5.7 BinaryMoment Struct Reference

Moment for binary variables.

```
#include <hnco/algorithms/hea/moment-binary.hh>
```

Public Member Functions

- [BinaryMoment](#) (int n)
Constructor.
- void [uniform](#) ()
Set the moment to that of the uniform distribution.
- void [init](#) ()
Initialize.
- void [add](#) (const [bit_vector_t](#) &x)
Accumulate a bit vector.
- void [average](#) (int count)
Compute average.
- void [update](#) (const [BinaryMoment](#) &p, double rate)
Update moment.

- void `bound` (double margin)
Bound moment.
- double `distance` (const `BinaryMoment` &p) const
Distance.
- double `norm_2` () const
Compute the norm 2.
- double `diameter` () const
Compute the diameter.
- size_t `size` () const
Size.

Public Attributes

- std::vector< std::vector< double > > `_moment`
Moment.
- double `_weight` = 1
Weight of second order moments.

5.7.1 Detailed Description

Moment for binary variables.

Definition at line 37 of file moment-binary.hh.

The documentation for this struct was generated from the following files:

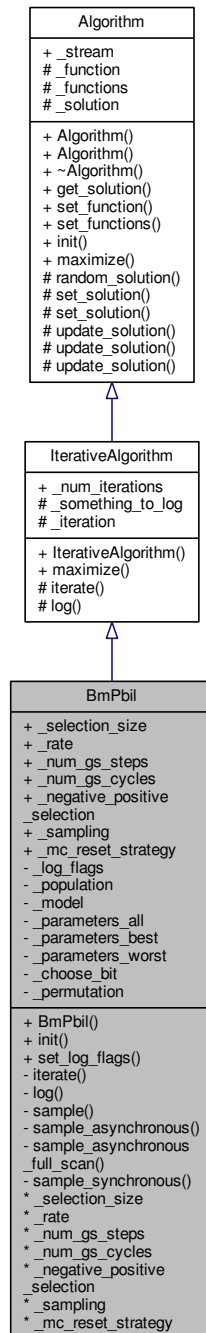
- lib/hnco/algorithms/hea/moment-binary.hh
- lib/hnco/algorithms/hea/moment-binary.cc

5.8 BmPbil Class Reference

Boltzmann machine PBIL.

```
#include <hnco/algorithms/bm-pbil/bm-pbil.hh>
```

Inheritance diagram for BmPbil:



Public Types

- enum { `LOG_NORM_INFINITE`, `LOG_NORM_L1`, **`LAST_LOG`** }
- enum { `SAMPLING_ASYNCHRONOUS`, `SAMPLING_ASYNCHRONOUS_FULL_SCAN`, `SAMPLING_SYNCHRONOUS` }
- enum { `RESET_NO_RESET`, `RESET_ITERATION`, `RESET_BIT_VECTOR` }
- typedef std::bitset< LAST_LOG > **`log_flags_t`**

Public Member Functions

- [BmPbil](#) (int n, int population_size)
Constructor.
- void [init](#) ()
Initialization.
- void [set_log_flags](#) (const log_flags_t &lf)
Set log flags.

Public Attributes

Parameters

- int [_selection_size](#) = 1
Selection size (number of selected individuals in the population)
- double [_rate](#) = 1e-3
Learning rate.
- int [_num_gs_steps](#) = 100
Number of gibbs sampler steps.
- int [_num_gs_cycles](#) = 1
Number of gibbs sampler cycles.
- bool [_negative_positive_selection](#) = false
Negative and positive selection.
- int [_sampling](#) = SAMPLING_ASYNCHRONOUS
Sampling mode.
- int [_mc_reset_strategy](#) = RESET_NO_RESET
MC reset strategy.

Private Member Functions

- void [iterate](#) ()
Single iteration.
- void [log](#) ()
Log.
- void [sample](#) (bit_vector_t &x)
Sample a bit vector.
- void [sample_asynchronous](#) ()
Asynchronous sampling.
- void [sample_asynchronous_full_scan](#) ()
Asynchronous sampling with full scan.
- void [sample_synchronous](#) ()
Synchronous sampling.

Private Attributes

- [log_flags_t _log_flags](#)
Log flags.
- [Population _population](#)
Population.
- [Model _model](#)
Model.
- [ModelParameters _parameters_all](#)
Parameters averaged over all individuals.
- [ModelParameters _parameters_best](#)
Parameters averaged over selected individuals.
- [ModelParameters _parameters_worst](#)
Parameters averaged over negatively selected individuals.
- [std::uniform_int_distribution< size_t > _choose_bit](#)
Uniform distribution on `bit_vector_t` components.
- [permutation_t _permutation](#)
Permutation.

Additional Inherited Members

5.8.1 Detailed Description

Boltzmann machine PBIL.

The BM model is slightly different from the one given in the reference below. More precisely, 0/1 variables are mapped to -1/+1 variables as in Walsh analysis.

Reference:

Arnaud Berny. 2002. Boltzmann machine for population-based incremental learning. In ECAI 2002. IOS Press, Lyon.

Definition at line 51 of file `bm-pbil.hh`.

5.8.2 Member Enumeration Documentation

5.8.2.1 anonymous enum

anonymous enum

Enumerator

<code>LOG_NORM_INFINITE</code>	Log infinite norm of the model parameters.
<code>LOG_NORM_L1</code>	Log 1-norm of the model parameters.

Definition at line 56 of file bm-pbil.hh.

5.8.2.2 anonymous enum

anonymous enum

Enumerator

SAMPLING_ASYNCHRONOUS	Asynchronous sampling. A single component of the internal state is randomly selected then updated by Gibbs sampling. This step is repeated <code>_num_gs_steps</code> times.
SAMPLING_ASYNCHRONOUS_FULL_SCAN	Asynchronous sampling with full scan. To sample a new bit vector, a random permutation is sampled and all components of the internal state are updated by Gibbs sampling in the order defined by the permutation.
SAMPLING_SYNCHRONOUS	Synchronous sampling. The full internal state is updated in one step from the probability vector made of the very marginal probabilities used in Gibbs sampling.

Definition at line 66 of file bm-pbil.hh.

5.8.2.3 anonymous enum

anonymous enum

Enumerator

RESET_NO_RESET	No reset.
RESET_ITERATION	Reset MC at the beginning of each iteration.
RESET_BIT_VECTOR	Reset MC before sampling each bit vector.

Definition at line 93 of file bm-pbil.hh.

The documentation for this class was generated from the following files:

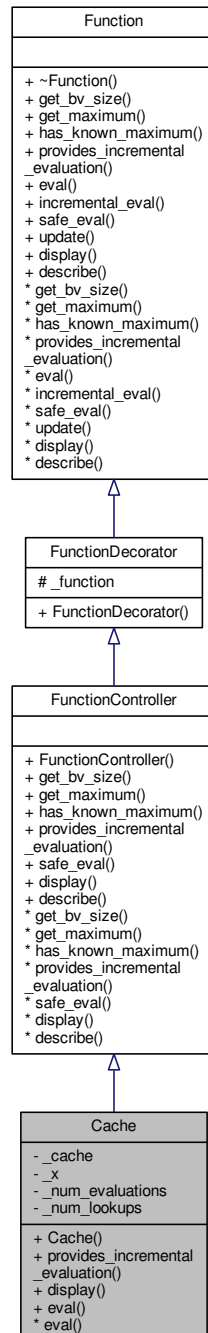
- `lib/hnco/algorithms/bm-pbil/bm-pbil.hh`
- `lib/hnco/algorithms/bm-pbil/bm-pbil.cc`

5.9 Cache Class Reference

[Cache.](#)

```
#include <hnco/functions/decorators/function-controller.hh>
```

Inheritance diagram for Cache:



Public Member Functions

- [Cache](#) ([Function](#) *function)
Constructor.
- bool [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.
- void [display](#) (std::ostream &stream)

Display.

Evaluation

- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.

Private Attributes

- `std::unordered_map< std::vector< bool >, double > _cache`
Database of past evaluations.
- `std::vector< bool > _x`
STL bit vector.
- `int _num_evaluations`
Evaluation counter.
- `int _num_lookups`
Lookup counter.

Additional Inherited Members

5.9.1 Detailed Description

`Cache`.

This is a naive approach, in particular with respect to time complexity. Moreover, there is no control on the size of the database.

There is no default hash function for `std::vector<char>` hence the need to first copy a `bit_vector_t` into a `std::vector<bool>`, for which such a function exists, before inserting it or checking its existence in the map.

Definition at line 344 of file `function-controller.hh`.

5.9.2 Constructor & Destructor Documentation

5.9.2.1 `Cache()`

```
Cache (
    Function * function ) [inline]
```

Constructor.

Parameters

<code>function</code>	Decorated function
-----------------------	--------------------

Definition at line 363 of file function-controller.hh.

5.9.3 Member Function Documentation

5.9.3.1 provides_incremental_evaluation()

```
bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

false

Reimplemented from [FunctionController](#).

Definition at line 372 of file function-controller.hh.

The documentation for this class was generated from the following files:

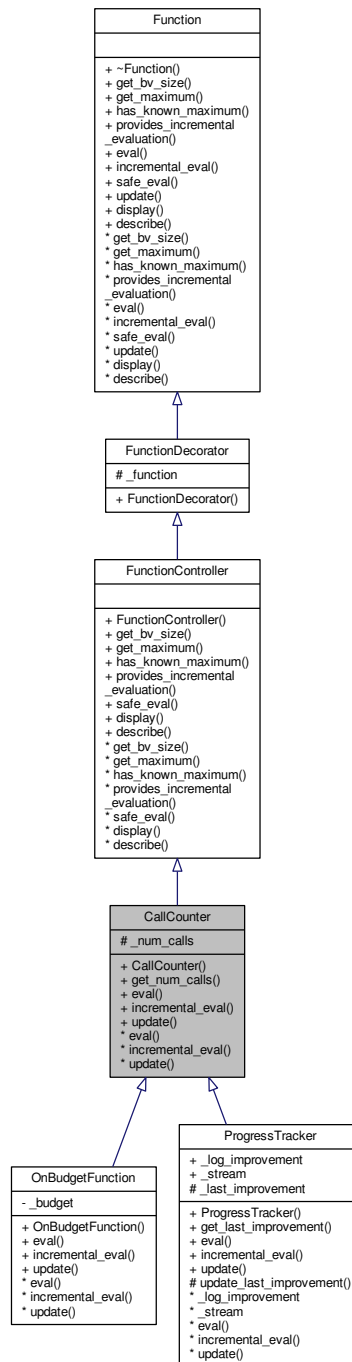
- lib/hnco/functions/decorators/function-controller.hh
- lib/hnco/functions/decorators/function-controller.cc

5.10 CallCounter Class Reference

Call counter.

```
#include <hnco/functions/decorators/function-controller.hh>
```


Inheritance diagram for CallCounter:



Public Member Functions

- **CallCounter (Function *function)**
Constructor.
- **int get_num_calls ()**
Get the number of calls.

Evaluation

- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.
- double `incremental_eval` (const `bit_vector_t` &x, double value, const `hnco::sparse_bit_vector_t` &flipped↔
_bits)
Incremental evaluation.
- void `update` (const `bit_vector_t` &x, double value)
Update after a safe evaluation.

Protected Attributes

- int `_num_calls`
Number of calls.

5.10.1 Detailed Description

Call counter.

Definition at line 170 of file `function-controller.hh`.

The documentation for this class was generated from the following files:

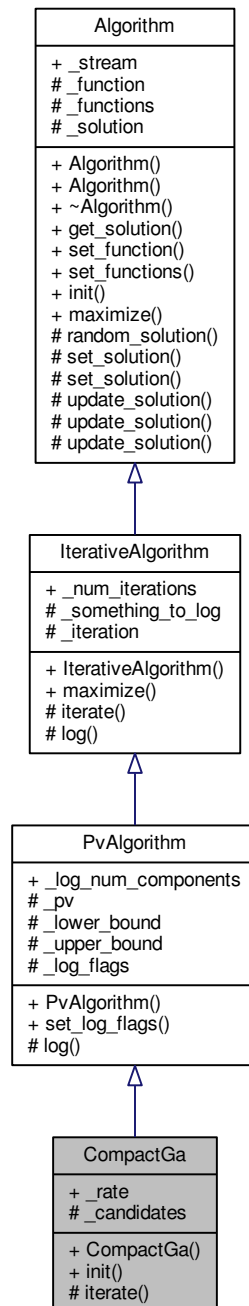
- `lib/hnco/functions/decorators/function-controller.hh`
- `lib/hnco/functions/decorators/function-controller.cc`

5.11 CompactGa Class Reference

Compact genetic algorithm.

```
#include <hnco/algorithms/pv/compact-ga.hh>
```

Inheritance diagram for CompactGa:



Public Member Functions

- [CompactGa](#) (int n)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

- double `_rate` = 1e-3
Learning rate.

Protected Member Functions

- void `iterate` ()
Single iteration.

Protected Attributes

- std::vector< `bit_vector_t` > `_candidates`
Candidates.

Additional Inherited Members

5.11.1 Detailed Description

Compact genetic algorithm.

Reference:

Georges R. Harik, Fernando G. Lobo, and David E. Goldberg. 1999. The Compact Genetic Algorithm. IEEE Trans. on Evolutionary Computation 3, 4 (November 1999), 287–297.

Definition at line 43 of file compact-ga.hh.

The documentation for this class was generated from the following files:

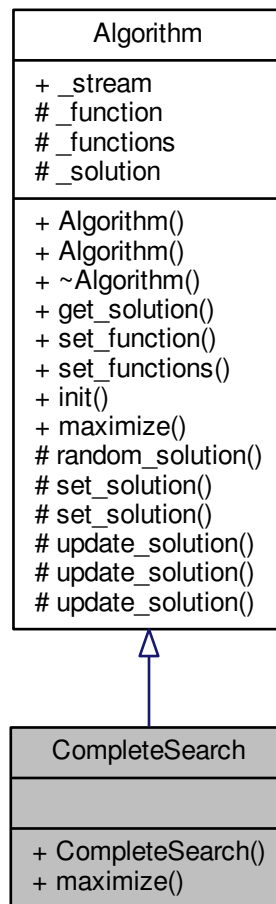
- lib/hnco/algorithms/pv/compact-ga.hh
- lib/hnco/algorithms/pv/compact-ga.cc

5.12 CompleteSearch Class Reference

Complete search.

```
#include <hnco/algorithms/complete-search.hh>
```

Inheritance diagram for CompleteSearch:



Public Member Functions

- [CompleteSearch](#) (int n)
Constructor.
- void [maximize](#) ()
Maximize.

Additional Inherited Members

5.12.1 Detailed Description

Complete search.

Definition at line 34 of file `complete-search.hh`.

The documentation for this class was generated from the following files:

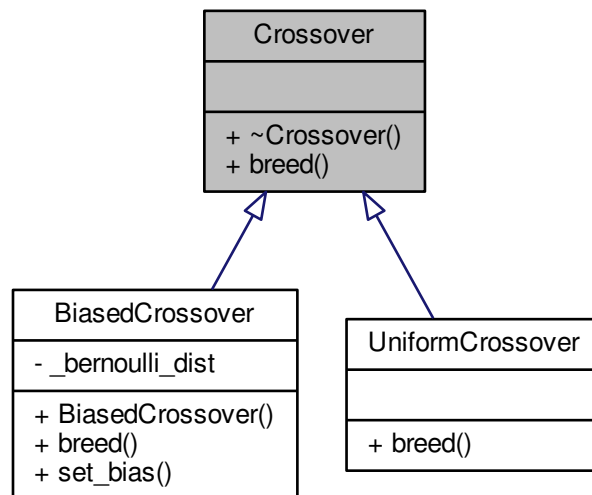
- `lib/hnco/algorithms/complete-search.hh`
- `lib/hnco/algorithms/complete-search.cc`

5.13 Crossover Class Reference

[Crossover](#).

```
#include <hnco/algorithms/ea/crossover.hh>
```

Inheritance diagram for Crossover:



Public Member Functions

- virtual `~Crossover()`
Destructor.
- virtual void `breed` (const `bit_vector_t` &parent1, const `bit_vector_t` &parent2, `bit_vector_t` &offspring)=0
Breed.

5.13.1 Detailed Description

[Crossover](#).

Definition at line 35 of file `crossover.hh`.

5.13.2 Member Function Documentation

5.13.2.1 breed()

```
virtual void breed (
    const bit\_vector\_t & parent1,
    const bit\_vector\_t & parent2,
    bit\_vector\_t & offspring ) [pure virtual]
```

Breed.

The offspring is the crossover of two parents.

Parameters

<i>parent1</i>	First parent
<i>parent2</i>	Second parent
<i>offspring</i>	Offspring

Implemented in [BiasedCrossover](#), and [UniformCrossover](#).

The documentation for this class was generated from the following file:

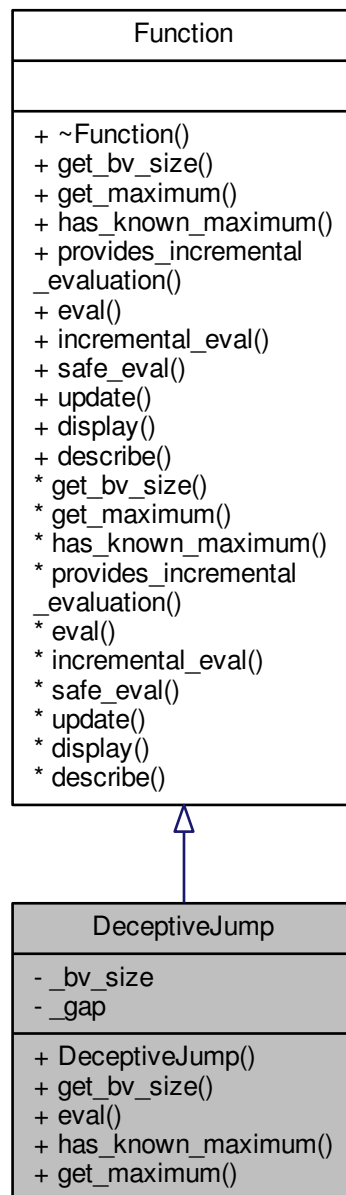
- `lib/hnco/algorithms/ea/crossover.hh`

5.14 DeceptiveJump Class Reference

Deceptive jump.

```
#include <hnco/functions/jump.hh>
```


Inheritance diagram for DeceptiveJump:



Public Member Functions

- [DeceptiveJump](#) (int bv_size, int gap)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

- bool [has_known_maximum](#) ()
Check for a known maximum.
- double [get_maximum](#) ()
Get the global maximum.

Private Attributes

- size_t [_bv_size](#)
Bit vector size.
- int [_gap](#)
Gap.

5.14.1 Detailed Description

Deceptive jump.

This is a jump function with a deceptive gap as defined in "Analyzing evolutionary algorithms" by Thomas Jansen, where it is called Jump_k. Algorithms in the neighborhood of the maximizer (which is the all one bit vector) are taken away from it.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 84 of file jump.hh.

5.14.2 Member Function Documentation

5.14.2.1 [get_maximum\(\)](#)

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

`_bv_size + _gap`

Reimplemented from [Function](#).

Definition at line 110 of file jump.hh.

5.14.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 106 of file jump.hh.

The documentation for this class was generated from the following files:

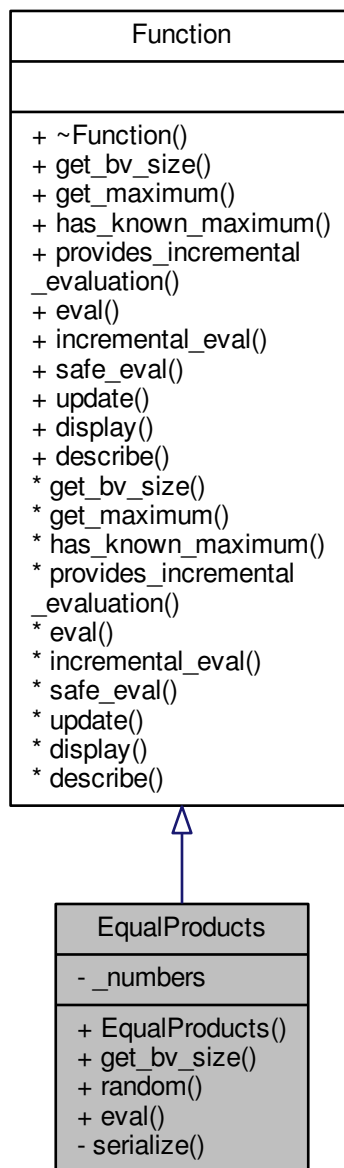
- lib/hnco/functions/jump.hh
- lib/hnco/functions/jump.cc

5.15 EqualProducts Class Reference

Equal products.

```
#include <hnco/functions/equal-products.hh>
```

Inheritance diagram for EqualProducts:



Public Member Functions

- [EqualProducts](#) ()
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `void` [random](#) (int n, double upper_bound)
Random instance.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

Private Member Functions

- `template<class Archive >`
void `serialize` (Archive &ar, const unsigned int version)
Serialize.

Private Attributes

- `std::vector< double > _numbers`
Numbers.

Friends

- class `boost::serialization::access`

5.15.1 Detailed Description

Equal products.

Partition a finite set of positive numbers into two subsets such that the product of numbers in the first subset is the closest to the product of numbers in the second subset. This is equivalent to the partition problem applied to the logarithms of the given numbers.

The function computes the negation of the distance between the product of numbers corresponding to ones in the bit vector and the product of those corresponding to zeros. The negation is a consequence of the fact that algorithms in HNCO maximize rather than minimize a function.

Reference:

S. Baluja and S. Davies. 1997. Using optimal dependency-trees for combinatorial optimization: learning the structure of the search space. Technical Report CMU- CS-97-107. Carnegie-Mellon University.

Definition at line 61 of file equal-products.hh.

5.15.2 Member Function Documentation

5.15.2.1 `random()`

```
void random (
    int n,
    double upper_bound )
```

Random instance.

Parameters

<i>n</i>	Size of bit vector
<i>upper_bound</i>	Upper bound of numbers

Generated by Doxygen

Definition at line 33 of file equal-products.cc.

The documentation for this class was generated from the following files:

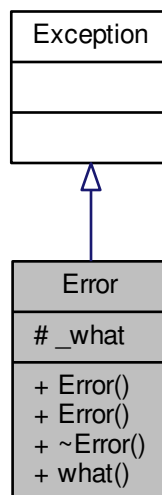
- lib/hnco/functions/equal-products.hh
- lib/hnco/functions/equal-products.cc

5.16 Error Class Reference

[Error](#).

```
#include <hnco/exception.hh>
```

Inheritance diagram for Error:



Public Member Functions

- [Error](#) ()
Constructor.
- [Error](#) (const std::string &s)
Constructor.
- virtual [~Error](#) ()
Destructor.
- virtual const char * [what](#) () const
Get message.

Protected Attributes

- `std::string _what`
Message.

5.16.1 Detailed Description

[Error.](#)

Definition at line 83 of file `exception.hh`.

The documentation for this class was generated from the following file:

- `lib/hnco/exception.hh`

5.17 ProgressTracker::Event Struct Reference

[Event.](#)

```
#include <hnco/functions/decorators/function-controller.hh>
```

Public Attributes

- `int time`
Time.
- `double value`
Value.

5.17.1 Detailed Description

[Event.](#)

Definition at line 218 of file `function-controller.hh`.

The documentation for this struct was generated from the following file:

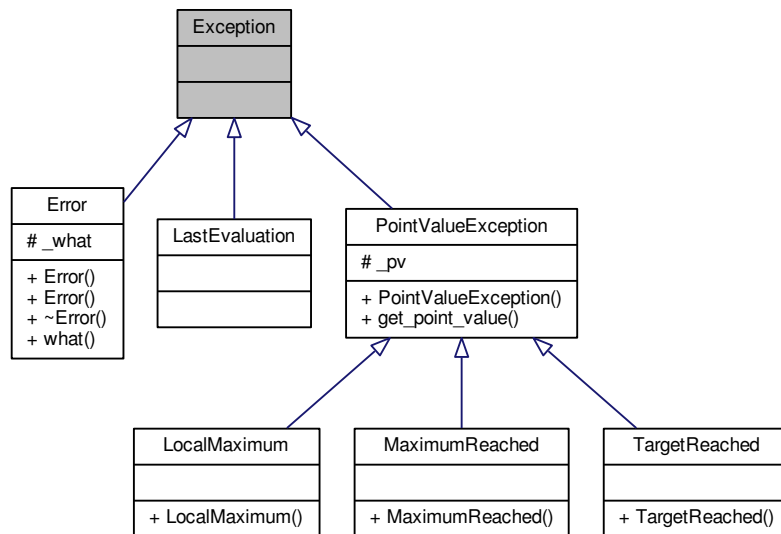
- `lib/hnco/functions/decorators/function-controller.hh`

5.18 Exception Class Reference

Basic exception.

```
#include <hnco/exception.hh>
```

Inheritance diagram for Exception:



5.18.1 Detailed Description

Basic exception.

Definition at line 35 of file exception.hh.

The documentation for this class was generated from the following file:

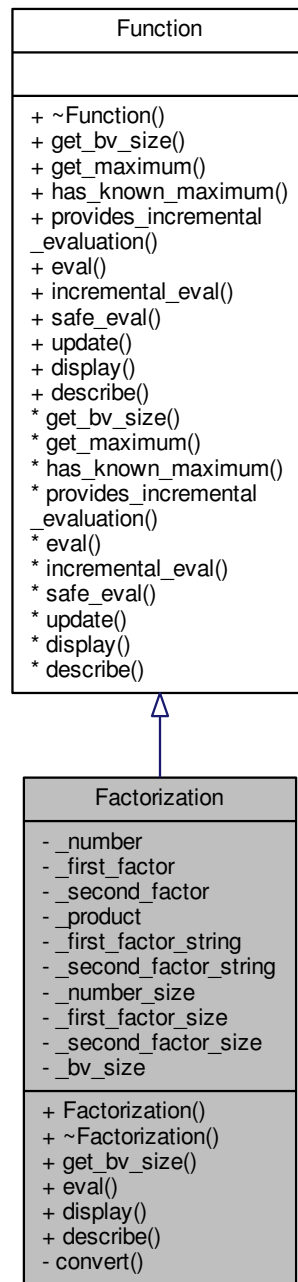
- lib/hnco/exception.hh

5.19 Factorization Class Reference

Factorization.

```
#include <hnco/functions/factorization.hh>
```


Inheritance diagram for Factorization:



Public Member Functions

- [Factorization](#) (std::string path)
Constructor.
- [~Factorization](#) ()
Destructor.
- `size_t get_bv_size ()`

- *Get bit vector size.*
double `eval` (const `bit_vector_t` &)
- *Evaluate a bit vector.*
void `display` (std::ostream &stream)
- *Display.*
void `describe` (const `bit_vector_t` &x, std::ostream &stream)
- *Describe a bit vector.*

Private Member Functions

- void `convert` (const `bit_vector_t` &x)
Convert a bit vector into two numbers.

Private Attributes

- `mpz_t _number`
Number to factorize.
- `mpz_t _first_factor`
First factor.
- `mpz_t _second_factor`
Second factor.
- `mpz_t _product`
Product.
- `std::string _first_factor_string`
First factor in binary form.
- `std::string _second_factor_string`
Secon factor in binary form.
- `size_t _number_size`
Number size in bits.
- `size_t _first_factor_size`
First factor size in bits.
- `size_t _second_factor_size`
Second factor size in bits.
- `size_t _bv_size`
Bit vector size.

5.19.1 Detailed Description

[Factorization.](#)

Reference:

Torbjörn Granlund and the GMP development team. 2012. GNU MP: The GNU Multiple Precision Arithmetic Library (5.0.5 ed.).

<http://gmplib.org/>.

Definition at line 28 of file factorization.hh.

5.19.2 Constructor & Destructor Documentation

5.19.2.1 Factorization()

```
Factorization (
    std::string path )
```

Constructor.

Parameters

<i>path</i>	Path to a file containing a number to factorize
-------------	---

Warning

The file is a text file which contains exactly one natural number written in base 10 without any space.

Definition at line 16 of file factorization.cc.

The documentation for this class was generated from the following files:

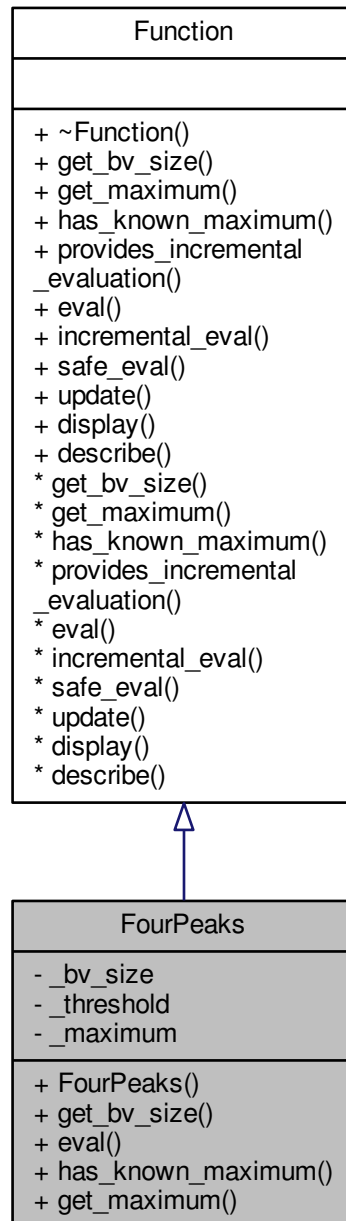
- lib/hnco/functions/factorization.hh
- lib/hnco/functions/factorization.cc

5.20 FourPeaks Class Reference

Four Peaks.

```
#include <hnco/functions/four-peaks.hh>
```

Inheritance diagram for FourPeaks:



Public Member Functions

- [FourPeaks](#) (int bv_size, int threshold)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)

Evaluate a bit vector.

- bool `has_known_maximum` ()

Check for a known maximum.

- double `get_maximum` ()

Get the global maximum.

Private Attributes

- size_t `_bv_size`

Bit vector size.

- int `_threshold`

Threshold.

- int `_maximum`

Maximum.

5.20.1 Detailed Description

Four Peaks.

It is defined by

$$f(x) = \max\{\text{head}(x, 1) + \text{tail}(x, 0)\} + R(x)$$

where:

- $\text{head}(x, 1)$ is the length of the longest prefix of x made of ones;
- $\text{tail}(x, 0)$ is the length of the longest suffix of x made of zeros;
- $R(x)$ is the reward;
- $R(x) = n$ if $(\text{head}(x, 1) > t \text{ and } \text{tail}(x, 0) > t)$;
- $R(x) = 0$ otherwise;
- the threshold t is a parameter of the function.

This function has four maxima, of which exactly two are global ones.

For example, if $n = 6$ and $t = 1$:

- $f(111111) = 6$ (local maximum)
- $f(111110) = 5$
- $f(111100) = 10$ (global maximum)

Reference:

S. Baluja and R. Caruana. 1995. Removing the genetics from the standard genetic algorithm. In Proceedings of the 12th Annual Conference on Machine Learning. 38–46.

Definition at line 60 of file four-peaks.hh.

5.20.2 Member Function Documentation

5.20.2.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

$2 * _bv_size - _threshold - 1$

Reimplemented from [Function](#).

Definition at line 91 of file four-peaks.hh.

5.20.2.2 `has_known_maximum()`

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 87 of file four-peaks.hh.

The documentation for this class was generated from the following files:

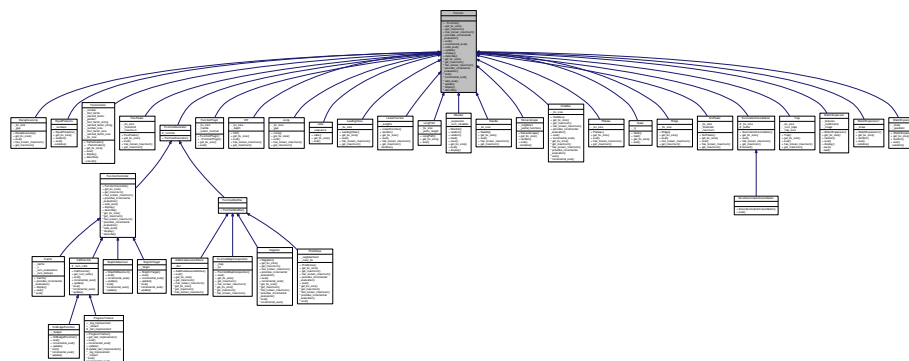
- lib/hnco/functions/four-peaks.hh
- lib/hnco/functions/four-peaks.cc

5.21 Function Class Reference

[Function](#).

```
#include <hnco/functions/function.hh>
```

Inheritance diagram for Function:



Public Member Functions

- virtual [~Function](#) ()
Destructor.

Information about the function

- virtual `size_t` [get_bv_size](#) ()=0
Get bit vector size.
- virtual `double` [get_maximum](#) ()
Get the global maximum.
- virtual `bool` [has_known_maximum](#) ()
Check for a known maximum.
- virtual `bool` [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.

Evaluation

- virtual `double` [eval](#) (const `bit_vector_t` &)=0
Evaluate a bit vector.
- virtual `double` [incremental_eval](#) (const `bit_vector_t` &x, `double` value, const `hnco::sparse_bit_vector_t` &flipped_bits)
Incremental evaluation.
- virtual `double` [safe_eval](#) (const `bit_vector_t` &x)
Safely evaluate a bit vector.
- virtual `void` [update](#) (const `bit_vector_t` &x, `double` value)
Update after a safe evaluation.

Display

- virtual `void` [display](#) (std::ostream &stream)
Display.
- virtual `void` [describe](#) (const `bit_vector_t` &x, std::ostream &stream)
Describe a bit vector.

5.21.1 Detailed Description

[Function.](#)

Definition at line 35 of file `function.hh`.

5.21.2 Member Function Documentation

5.21.2.1 [get_maximum\(\)](#)

```
virtual double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Exceptions

Error	
-------	--

Reimplemented in [Plateau](#), [Ridge](#), [Hiff](#), [AdditiveGaussianNoise](#), [SixPeaks](#), [Needle](#), [FunctionMapComposition](#), [LeadingOnes](#), [DeceptiveJump](#), [FourPeaks](#), [SummationCancellation](#), [Trap](#), [LinearFunction](#), [Negation](#), [PriorNoise](#), [Jump](#), [OneMax](#), and [FunctionController](#).

Definition at line 51 of file function.hh.

5.21.2.2 incremental_eval()

```
virtual double incremental_eval (
    const bit\_vector\_t & x,
    double value,
    const hnco::sparse\_bit\_vector\_t & flipped_bits ) [inline], [virtual]
```

Incremental evaluation.

Exceptions

Error	
-------	--

Reimplemented in [OnBudgetFunction](#), [ProgressTracker](#), [CallCounter](#), [StopOnTarget](#), [StopOnMaximum](#), [Negation](#), and [OneMax](#).

Definition at line 75 of file function.hh.

5.21.2.3 provides_incremental_evaluation()

```
virtual bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

false

Reimplemented in [Cache](#), [Negation](#), [PriorNoise](#), [OneMax](#), and [FunctionController](#).

Definition at line 59 of file function.hh.

5.21.2.4 `safe_eval()`

```
virtual double safe_eval (  
    const bit\_vector\_t & x ) [inline], [virtual]
```

Safely evaluate a bit vector.

Must be thread-safe, that is must avoid throwing exceptions and updating global states (e.g. maximum) in function decorators.

Reimplemented in [FunctionController](#).

Definition at line 85 of file `function.hh`.

The documentation for this class was generated from the following file:

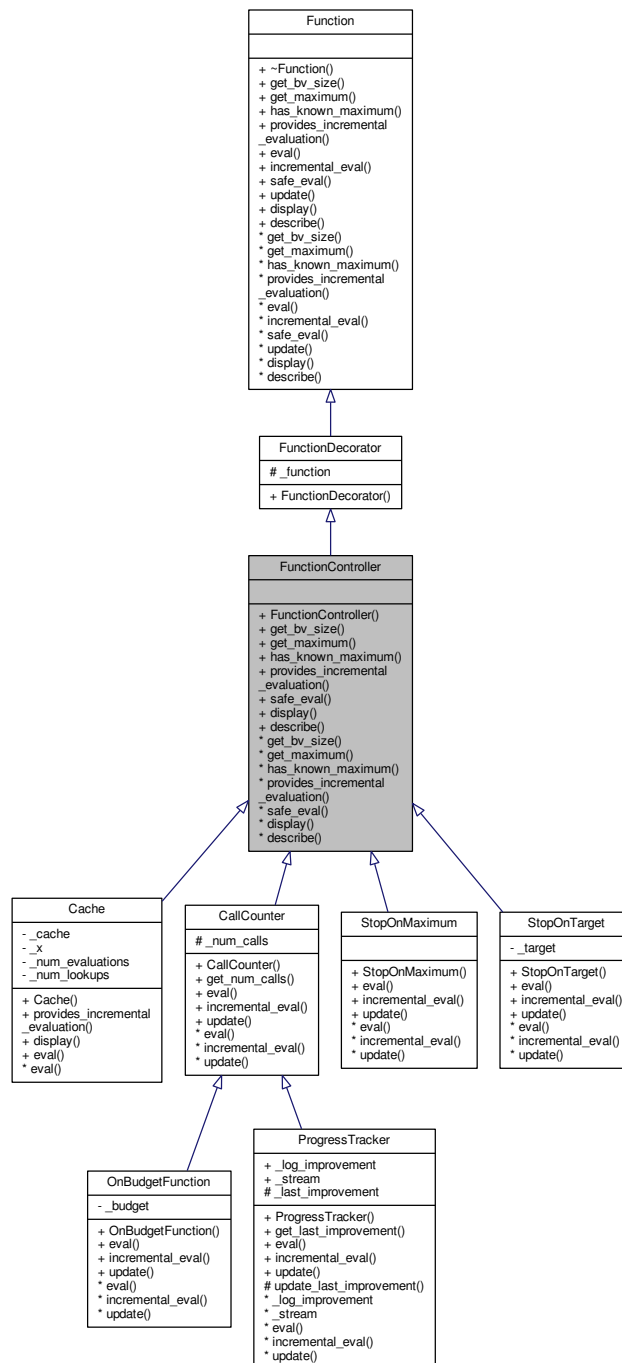
- `lib/hnco/functions/function.hh`

5.22 FunctionController Class Reference

[Function](#) controller.

```
#include <hnco/functions/decorators/function-controller.hh>
```

Inheritance diagram for FunctionController:



Public Member Functions

- **FunctionController** (**Function** *function)

Constructor.

Information about the function

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [get_maximum](#) ()
Get the global maximum.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.
- `bool` [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.

Evaluation

- `double` [safe_eval](#) (const `bit_vector_t` &x)
Safely evaluate a bit vector.

Display

- `void` [display](#) (std::ostream &stream)
Display.
- `void` [describe](#) (const `bit_vector_t` &x, std::ostream &stream)
Describe a bit vector.

Additional Inherited Members

5.22.1 Detailed Description

[Function](#) controller.

Definition at line 38 of file `function-controller.hh`.

5.22.2 Member Function Documentation

5.22.2.1 [provides_incremental_evaluation\(\)](#)

```
bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

true if the decorated function does

Reimplemented from [Function](#).

Reimplemented in [Cache](#).

Definition at line 63 of file `function-controller.hh`.

The documentation for this class was generated from the following file:

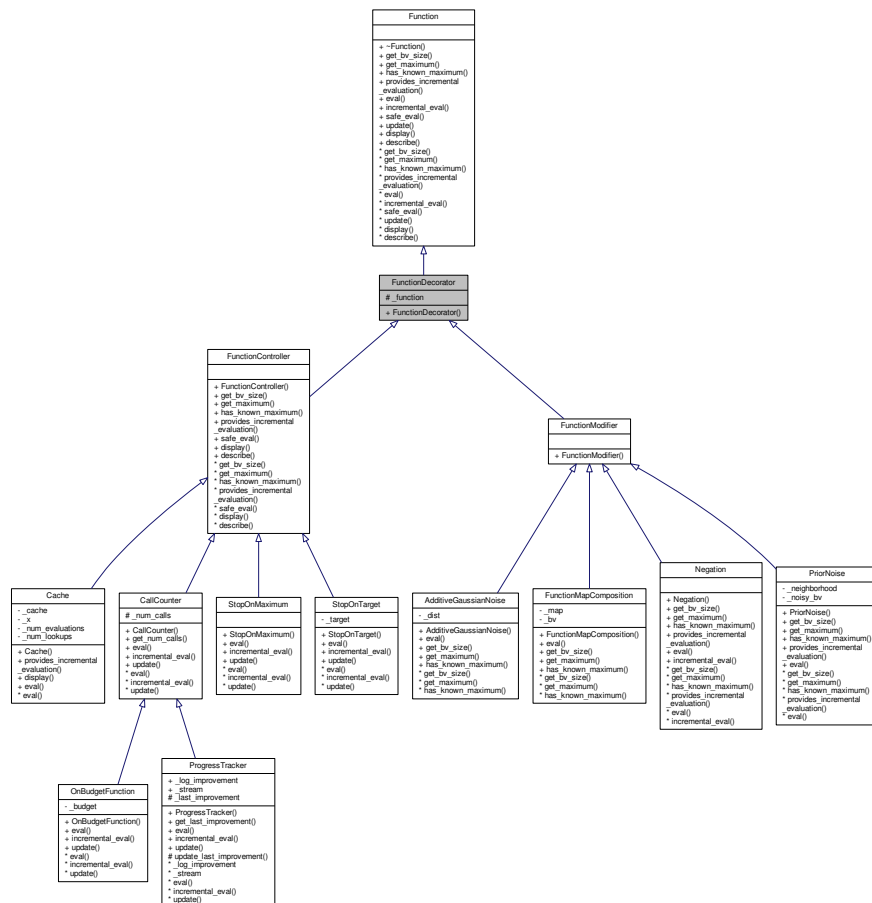
- `lib/hnco/functions/decorators/function-controller.hh`

5.23 FunctionDecorator Class Reference

Function decorator.

```
#include <hnco/functions/decorators/function-decorator.hh>
```

Inheritance diagram for FunctionDecorator:



Public Member Functions

- [FunctionDecorator](#) ([Function](#) *function)

Constructor.

Protected Attributes

- [Function](#) * [_function](#)

Decorated function.

5.23.1 Detailed Description

Function decorator.

Definition at line 37 of file function-decorator.hh.

The documentation for this class was generated from the following file:

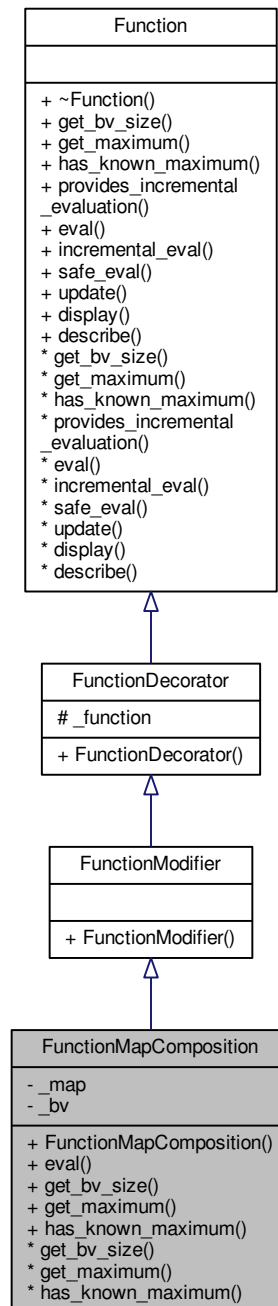
- lib/hnco/functions/decorators/function-decorator.hh

5.24 FunctionMapComposition Class Reference

Composition of a function and a map.

```
#include <hnco/functions/decorators/function-modifier.hh>
```

Inheritance diagram for FunctionMapComposition:



Public Member Functions

- `FunctionMapComposition` (`Function` *function, `Map` *map)

Constructor.

- `double eval` (const `bit_vector_t` &)

Evaluate a bit vector.

Information about the function

- `size_t` `get_bv_size()`
Get bit vector size.
- `double` `get_maximum()`
Get the global maximum.
- `bool` `has_known_maximum()`
Check for a known maximum.

Private Attributes

- `Map *` `_map`
Map.
- `bit_vector_t` `_bv`
_bv

Additional Inherited Members**5.24.1 Detailed Description**

Composition of a function and a map.

Definition at line 106 of file `function-modifier.hh`.

5.24.2 Constructor & Destructor Documentation**5.24.2.1 FunctionMapComposition()**

```
FunctionMapComposition (
    Function * function,
    Map * map ) [inline]
```

Constructor.

Precondition

`map->get_output_size() == function->get_bv_size()`

Exceptions

Error	
-------	--

Definition at line 121 of file `function-modifier.hh`.

5.24.3 Member Function Documentation

5.24.3.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Exceptions

<i>Error</i>	
--------------	--

Reimplemented from [Function](#).

Definition at line 141 of file function-modifier.hh.

5.24.3.2 `has_known_maximum()`

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true if the function has a known maximum and the map is bijective.

Reimplemented from [Function](#).

Definition at line 151 of file function-modifier.hh.

The documentation for this class was generated from the following files:

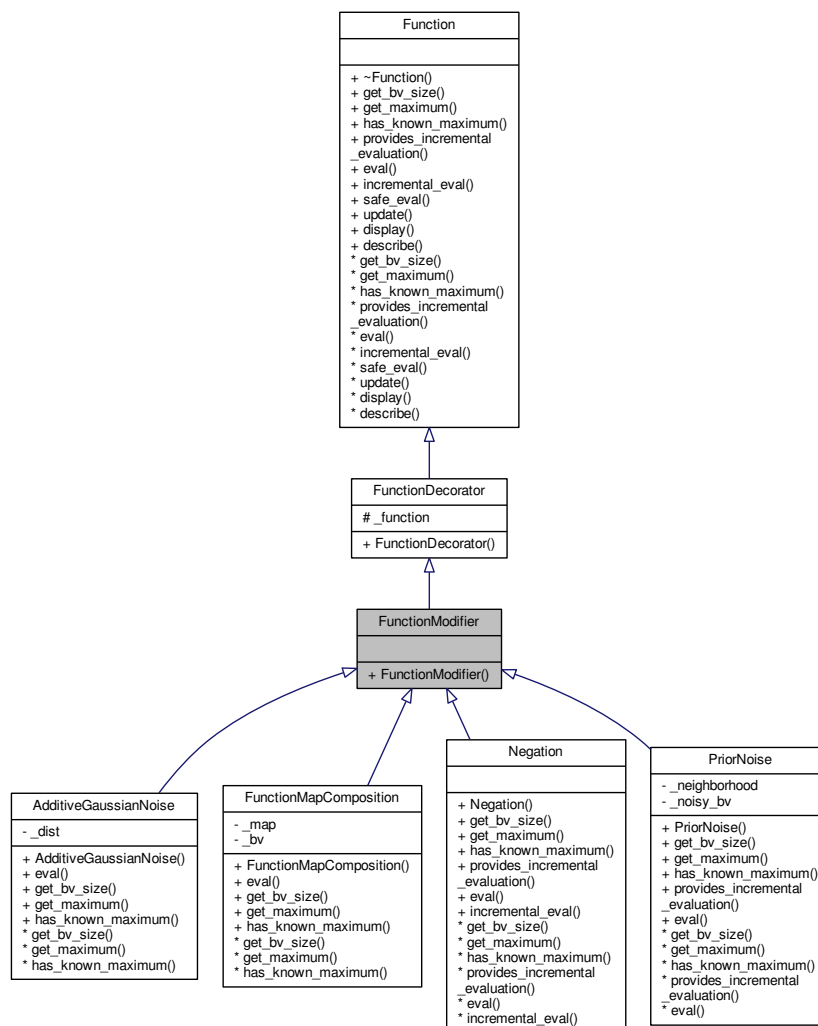
- lib/hnco/functions/decorators/function-modifier.hh
- lib/hnco/functions/decorators/function-modifier.cc

5.25 FunctionModifier Class Reference

Function modifier.

```
#include <hnco/functions/decorators/function-modifier.hh>
```

Inheritance diagram for FunctionModifier:



Public Member Functions

- **FunctionModifier** (**Function** *function)

Constructor.

Additional Inherited Members

5.25.1 Detailed Description

[Function](#) modifier.

Definition at line 37 of file function-modifier.hh.

The documentation for this class was generated from the following file:

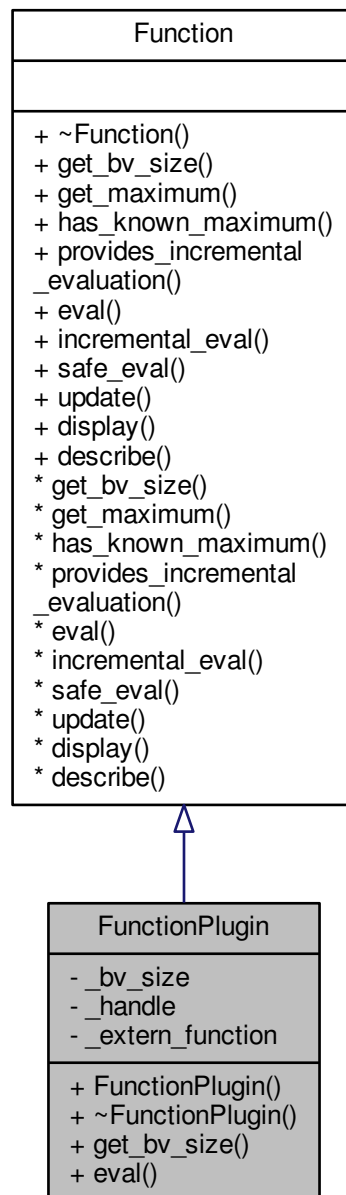
- lib/hnco/functions/decorators/function-modifier.hh

5.26 FunctionPlugin Class Reference

[Function](#) plugin.

```
#include <hnco/functions/plugin.hh>
```

Inheritance diagram for FunctionPlugin:



Public Member Functions

- [FunctionPlugin](#) (int bv_size, std::string path, std::string name)
Constructor.
- [~FunctionPlugin](#) ()
Destructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.

- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.

Private Types

- typedef double(* `extern_function_t`) (const char[], size_t)
Type of an extern function.

Private Attributes

- size_t `_bv_size`
Bit vector size.
- void * `_handle`
Handle returned by dlopen.
- `extern_function_t` `_extern_function`
Extern function.

5.26.1 Detailed Description

`Function` plugin.

Definition at line 34 of file `plugin.hh`.

5.26.2 Constructor & Destructor Documentation

5.26.2.1 FunctionPlugin()

```
FunctionPlugin (
    int bv_size,
    std::string path,
    std::string name )
```

Constructor.

Parameters

<i>bv_size</i>	Size of bit vectors
<i>path</i>	Path to a shared library
<i>name</i>	Name of a function of the shared library

Definition at line 35 of file `plugin.cc`.

The documentation for this class was generated from the following files:

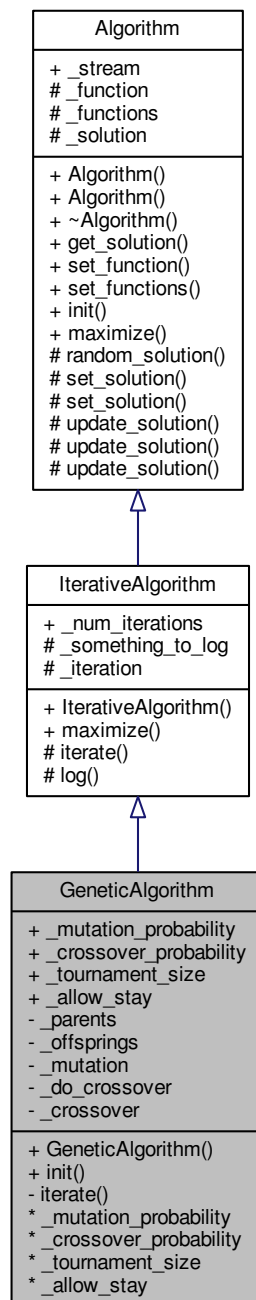
- lib/hnco/functions/plugin.hh
- lib/hnco/functions/plugin.cc

5.27 GeneticAlgorithm Class Reference

Genetic algorithm.

```
#include <hnco/algorithms/ea/genetic-algorithm.hh>
```

Inheritance diagram for GeneticAlgorithm:



Public Member Functions

- [GeneticAlgorithm](#) (int n, int mu)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- double [_mutation_probability](#)
Mutation probability.
- double [_crossover_probability](#) = 0.5
Crossover probability.
- int [_tournament_size](#) = 10
Tournament size.
- bool [_allow_stay](#) = false
Allow stay.

Private Member Functions

- void [iterate](#) ()
Single iteration.

Private Attributes

- [TournamentSelection](#) [_parents](#)
Parents.
- [TournamentSelection](#) [_offsprings](#)
Offsprings.
- [neighborhood::BernoulliProcess](#) [_mutation](#)
Mutation operator.
- [std::bernoulli_distribution](#) [_do_crossover](#)
Do crossover.
- [UniformCrossover](#) [_crossover](#)
Uniform crossover.

Additional Inherited Members

5.27.1 Detailed Description

Genetic algorithm.

- Tournament selection for reproduction
- Uniform crossover
- Mutation
- (mu, mu) selection (offspring population replaces parent population)

Reference:

J. H. Holland. 1975. Adaptation in natural and artificial systems. University of Michigan Press, Ann Arbor.

Definition at line 51 of file genetic-algorithm.hh.

5.27.2 Constructor & Destructor Documentation

5.27.2.1 GeneticAlgorithm()

```
GeneticAlgorithm (
    int n,
    int mu ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
<i>mu</i>	Population size

Definition at line 79 of file genetic-algorithm.hh.

5.27.3 Member Data Documentation

5.27.3.1 _allow_stay

```
bool _allow_stay = false
```

Allow stay.

In case no mutation occurs allow the current bit vector to stay unchanged.

Definition at line 107 of file genetic-algorithm.hh.

The documentation for this class was generated from the following files:

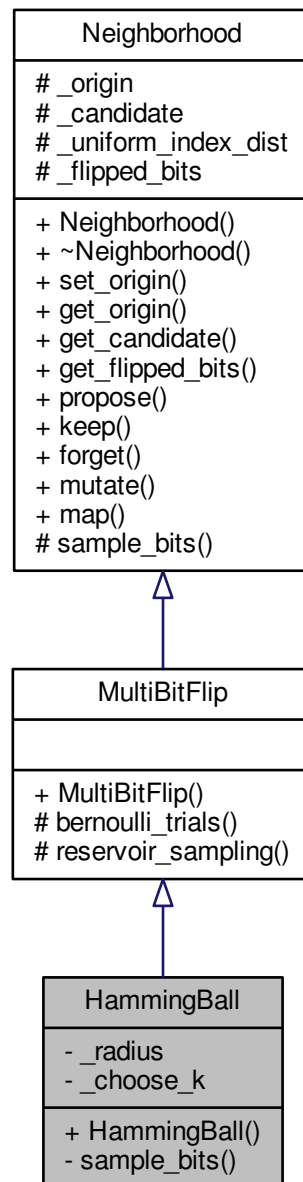
- lib/hnco/algorithms/ea/genetic-algorithm.hh
- lib/hnco/algorithms/ea/genetic-algorithm.cc

5.28 HammingBall Class Reference

Hamming ball.

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for HammingBall:



Public Member Functions

- [HammingBall](#) (int n, int r)
Constructor.

Private Member Functions

- void `sample_bits()`
Sample bits.

Private Attributes

- int `_radius`
Radius of the ball.
- `std::uniform_int_distribution< int > _choose_k`
Choose the distance to the center.

Additional Inherited Members

5.28.1 Detailed Description

Hamming ball.

Choose k uniformly on $[1..r]$, where r is the radius of the ball, choose k bits uniformly among n and flip them.

Definition at line 295 of file `neighborhood.hh`.

5.28.2 Constructor & Destructor Documentation

5.28.2.1 HammingBall()

```
HammingBall (
    int  $n$ ,
    int  $r$  ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
r	Radius of the ball

Definition at line 314 of file `neighborhood.hh`.

The documentation for this class was generated from the following files:

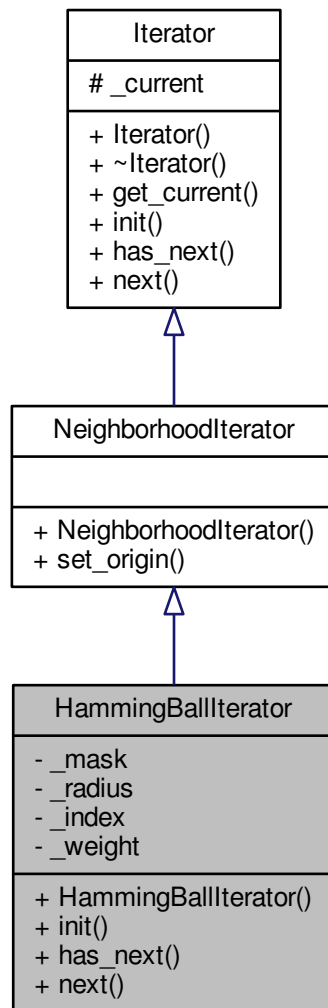
- `lib/hnco/neighborhoods/neighborhood.hh`
- `lib/hnco/neighborhoods/neighborhood.cc`

5.29 HammingBallIterator Class Reference

Hamming ball neighborhood iterator.

```
#include <hnco/neighborhoods/neighborhood-iterator.hh>
```

Inheritance diagram for HammingBallIterator:



Public Member Functions

- [HammingBallIterator](#) (int n, int r)
Constructor.
- void [init](#) ()
Initialization.
- bool [has_next](#) ()
Has next bit vector.
- void [next](#) ()
Next bit vector.

Private Attributes

- [bit_vector_t _mask](#)
Mutation mask.
- [int _radius](#)
Radius of the ball.
- [int _index](#)
Index of the next bit to shift to the right.
- [int _weight](#)
Partial Hamming weight.

Additional Inherited Members

5.29.1 Detailed Description

Hamming ball neighborhood iterator.

Definition at line 86 of file neighborhood-iterator.hh.

5.29.2 Constructor & Destructor Documentation

5.29.2.1 HammingBallIterator()

```
HammingBallIterator (
    int n,
    int r ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
<i>r</i>	Radius of Hamming Ball

Definition at line 108 of file neighborhood-iterator.hh.

The documentation for this class was generated from the following files:

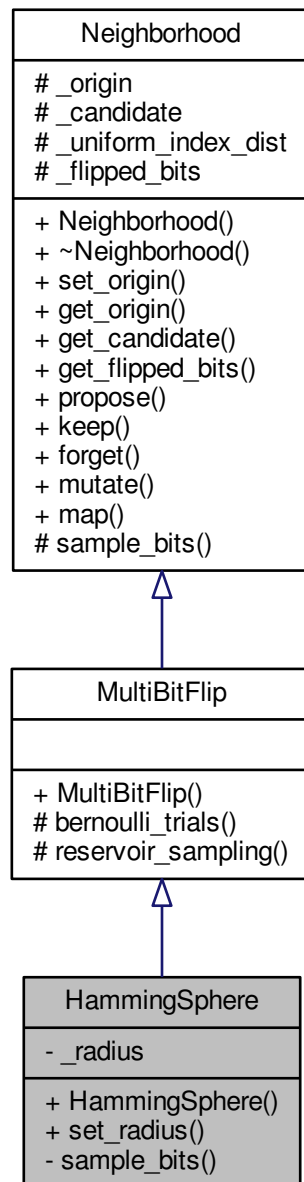
- lib/hnco/neighborhoods/neighborhood-iterator.hh
- lib/hnco/neighborhoods/neighborhood-iterator.cc

5.30 HammingSphere Class Reference

Hamming sphere.

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for HammingSphere:



Public Member Functions

- [HammingSphere](#) (int n, int r)
Constructor.
- void [set_radius](#) (int r)
Set radius.

Private Member Functions

- void `sample_bits` ()
Sample bits.

Private Attributes

- int `_radius`
Radius of the sphere.

Additional Inherited Members

5.30.1 Detailed Description

Hamming sphere.

Uniformly choose r bits among n and flip them, where r is the radius of the sphere.

Definition at line 332 of file `neighborhood.hh`.

5.30.2 Constructor & Destructor Documentation

5.30.2.1 HammingSphere()

```
HammingSphere (
    int n,
    int r ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
r	Radius of the sphere

Definition at line 348 of file `neighborhood.hh`.

The documentation for this class was generated from the following files:

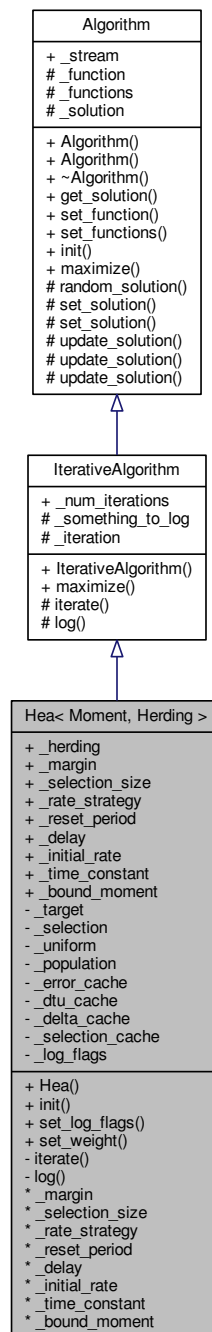
- `lib/hnco/neighborhoods/neighborhood.hh`
- `lib/hnco/neighborhoods/neighborhood.cc`

5.31 Hea< Moment, Herding > Class Template Reference

Herding evolutionary algorithm.

```
#include <hnco/algorithms/hea/hea.hh>
```

Inheritance diagram for Hea< Moment, Herding >:



Public Types

- enum {
LOG_ERROR, LOG_DTU, LOG_DELTA, LOG_SELECTION,
LAST_LOG }
- enum { RATE_CONSTANT, RATE_EXPONENTIAL, RATE_INVERSE }
- typedef std::bitset< LAST_LOG > log_flags_t

Type for log flags.

Public Member Functions

- Hea (int n, int population_size)
Constructor.
- void init ()
Initialization.
- void set_log_flags (const log_flags_t &lf)
Set log flags.
- void set_weight (double weight)
Set weight.

Public Attributes

- Herding _herding
Herding.

Parameters

- double _margin
Moment margin.
- int _selection_size = 1
Selection size (number of selected individuals in the population)
- int _rate_strategy = RATE_CONSTANT
Rate strategy.
- int _reset_period = 0
Reset period (<= 0 means no reset)
- int _delay = 10000
Delay.
- double _initial_rate = 1e-4
Initial value of the learning rate.
- double _time_constant = 1000
Time constant.
- bool _bound_moment = false
Bound moment after update.

Private Member Functions

- void iterate ()
Single iteration.
- void log ()
Log.

Private Attributes

- [Moment _target](#)
Moment.
- [Moment _selection](#)
Moment of selected individuals.
- [Moment _uniform](#)
Uniform moment.
- [algorithm::Population _population](#)
Population.
- [double _error_cache](#)
Error cache.
- [double _dtu_cache](#)
Distance to uniform cache.
- [double _delta_cache](#)
Delta cache.
- [double _selection_cache](#)
Selection distance cache.
- [log_flags_t _log_flags](#)
Log flags.

Additional Inherited Members

5.31.1 Detailed Description

```
template<class Moment, class Herding>
class hnco::algorithm::hea::Hea< Moment, Herding >
```

Herding evolutionary algorithm.

Reference:

Arnaud Berny. 2015. Herding Evolutionary Algorithm. In Proceedings of the Companion Publication of the 2015 Annual Conference on Genetic and Evolutionary Computation (GECCO Companion '15). ACM, New York, NY, USA, 1355–1356.

Definition at line 49 of file hea.hh.

5.31.2 Member Enumeration Documentation

5.31.2.1 anonymous enum

```
anonymous enum
```


Enumerator

LOG_ERROR	Log error.
LOG_DTU	Log distance to uniform.
LOG_DELTA	Log delta (moment increment)
LOG_SELECTION	Log the distance between the target and the selection moment.

Definition at line 54 of file hea.hh.

5.31.2.2 anonymous enum

anonymous enum

Enumerator

RATE_CONSTANT	Constant rate.
RATE_EXPONENTIAL	Exponentiel decay.
RATE_INVERSE	Inverse decay.

Definition at line 202 of file hea.hh.

The documentation for this class was generated from the following file:

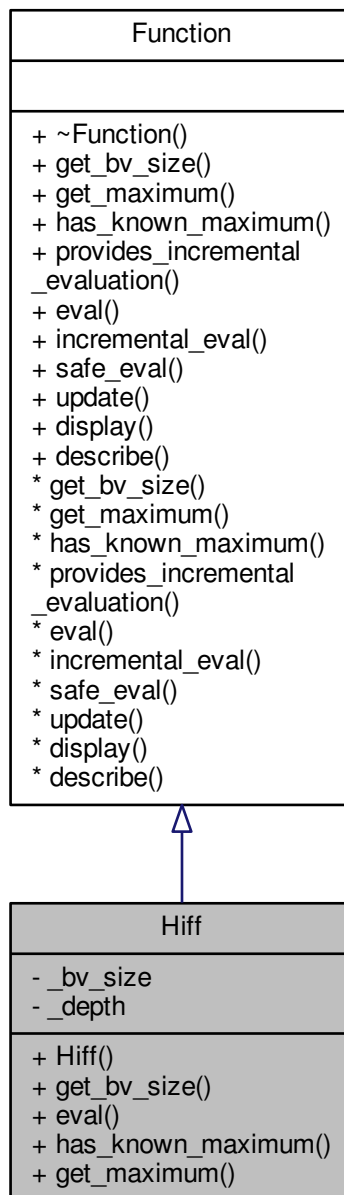
- lib/hnco/algorithms/hea/hea.hh

5.32 Hiff Class Reference

Hierarchical if and only if.

```
#include <hnco/functions/theory.hh>
```

Inheritance diagram for Hiff:



Public Member Functions

- [Hiff](#) (int bv_size)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

- bool [has_known_maximum](#) ()
Check for a known maximum.
- double [get_maximum](#) ()
Get the global maximum.

Private Attributes

- size_t [_bv_size](#)
Bit vector size.
- size_t [_depth](#)
Tree depth.

5.32.1 Detailed Description

Hierarchical if and only if.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 165 of file theory.hh.

5.32.2 Member Function Documentation

5.32.2.1 [get_maximum\(\)](#)

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

$(i + 1) * 2^i$ where $2^i = _bv_size$

Reimplemented from [Function](#).

Definition at line 191 of file theory.hh.

5.32.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 187 of file theory.hh.

The documentation for this class was generated from the following files:

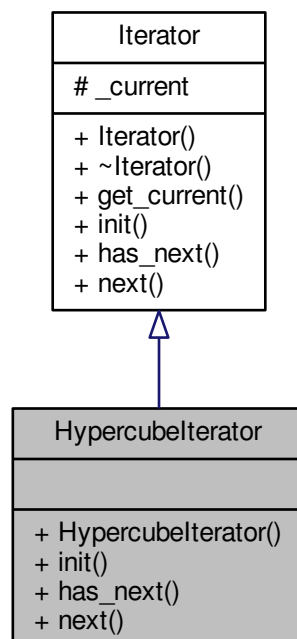
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.33 Hypercubeliterator Class Reference

Hypercube iterator.

```
#include <hnco/iterator.hh>
```

Inheritance diagram for Hypercubeliterator:



Public Member Functions

- [Hypercubeliterator](#) (int n)
Constructor.
- void [init](#) ()
Initialization.
- bool [has_next](#) ()
Has next bit vector.
- void [next](#) ()
Next bit vector.

Additional Inherited Members

5.33.1 Detailed Description

Hypercube iterator.

Definition at line 71 of file iterator.hh.

5.33.2 Member Function Documentation

5.33.2.1 [next\(\)](#)

```
void next ( ) [virtual]
```

Next bit vector.

Implemented as a simple binary adder.

Implements [Iterator](#).

Definition at line 28 of file iterator.cc.

The documentation for this class was generated from the following files:

- lib/hnco/iterator.hh
- lib/hnco/iterator.cc

5.34.1 Detailed Description

Iterative search.

Definition at line 115 of file algorithm.hh.

5.34.2 Constructor & Destructor Documentation

5.34.2.1 IterativeAlgorithm()

```
IterativeAlgorithm (
    int n ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
-----	---------------------

Definition at line 137 of file algorithm.hh.

5.34.3 Member Function Documentation

5.34.3.1 maximize()

```
void maximize ( ) [virtual]
```

Maximize.

Inside the loop:

- call [iterate\(\)](#)
- call [log\(\)](#)

Warning

If an exception such as LocalMaximum is thrown by [iterate\(\)](#), [log\(\)](#) will not be called. However, hnco reports the maximum at the end of the search.

Implements [Algorithm](#).

Definition at line 77 of file algorithm.cc.

5.34.4 Member Data Documentation

5.34.4.1 `_num_iterations`

```
int _num_iterations = 0
```

Number of iterations.

`_num_iterations <= 0` means indefinite

Definition at line 154 of file `algorithm.hh`.

The documentation for this class was generated from the following files:

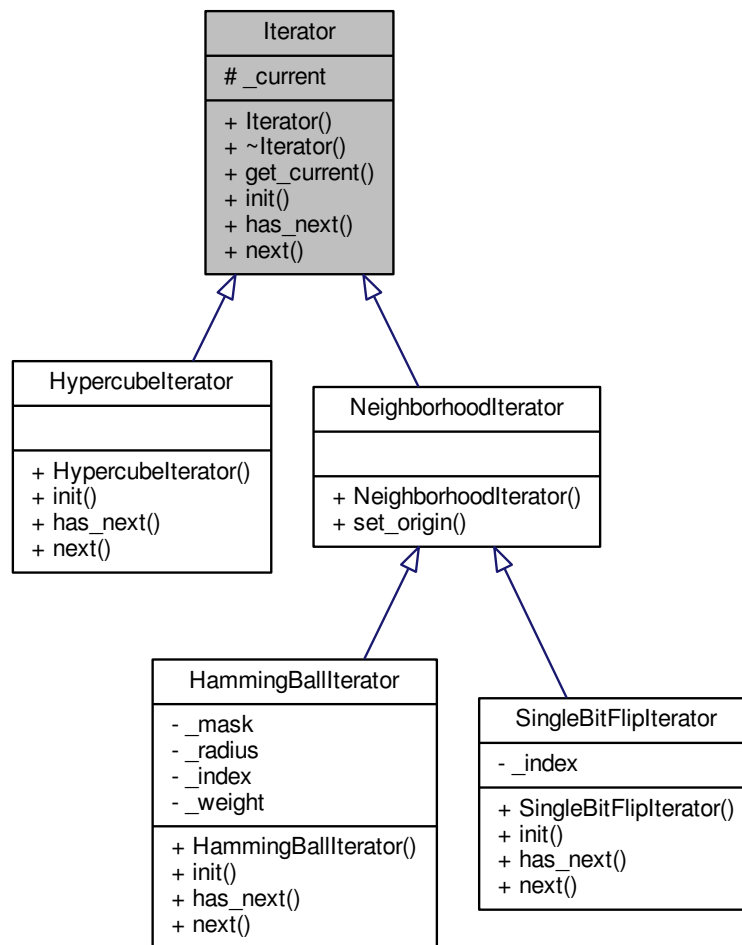
- `lib/hnco/algorithms/algorithm.hh`
- `lib/hnco/algorithms/algorithm.cc`

5.35 Iterator Class Reference

[Iterator](#) over bit vectors.

```
#include <hnco/iterator.hh>
```


Inheritance diagram for Iterator:



Public Member Functions

- `Iterator` (int n)
Constructor.
- virtual `~Iterator` ()
Destructor.
- virtual const `bit_vector_t` & `get_current` ()
Current bit vector.
- virtual void `init` ()=0
Initialization.
- virtual bool `has_next` ()=0
Has next bit vector.
- virtual void `next` ()=0
Next bit vector.

Protected Attributes

- [bit_vector_t _current](#)

Current bit vector.

5.35.1 Detailed Description

[Iterator](#) over bit vectors.

Definition at line 40 of file iterator.hh.

The documentation for this class was generated from the following file:

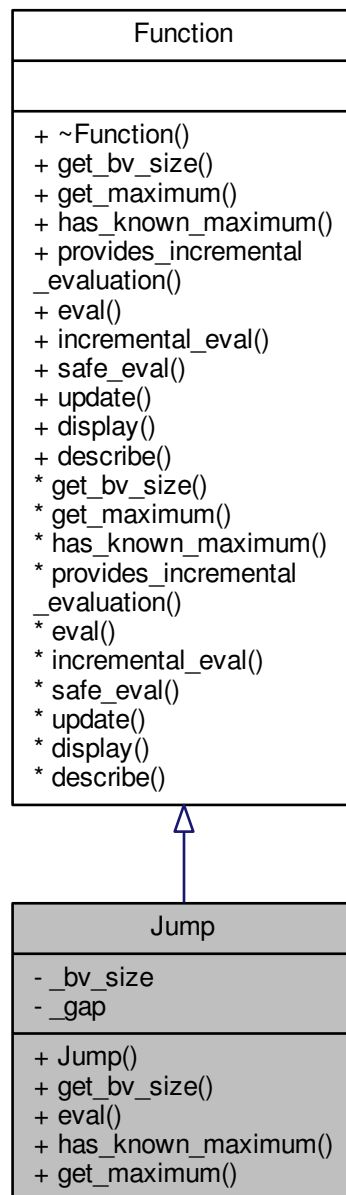
- lib/hnco/iterator.hh

5.36 Jump Class Reference

[Jump](#).

```
#include <hnco/functions/jump.hh>
```

Inheritance diagram for Jump:



Public Member Functions

- [Jump](#) (int bv_size, int gap)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

- bool [has_known_maximum](#) ()
Check for a known maximum.
- double [get_maximum](#) ()
Get the global maximum.

Private Attributes

- size_t [_bv_size](#)
Bit vector size.
- int [_gap](#)
Gap.

5.36.1 Detailed Description

[Jump](#).

Reference:

H. Mühlenbein and T. Mahnig. 2001. Evolutionary Algorithms: From Recombination to Search Distributions. In Theoretical Aspects of Evolutionary Computing, Leila Kallel, Bart Naudts, and Alex Rogers (Eds.). Springer Berlin Heidelberg, 135–174.

Definition at line 40 of file jump.hh.

5.36.2 Member Function Documentation

5.36.2.1 [get_maximum\(\)](#)

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

[_bv_size](#)

Reimplemented from [Function](#).

Definition at line 66 of file jump.hh.

5.36.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 62 of file jump.hh.

The documentation for this class was generated from the following files:

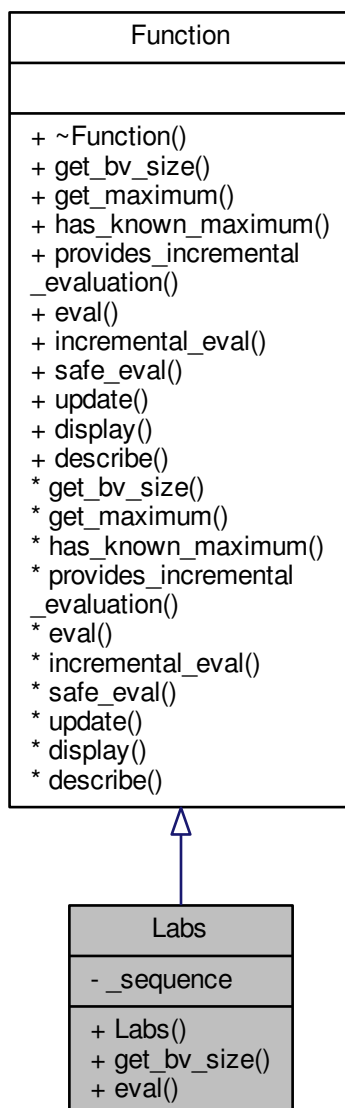
- lib/hnco/functions/jump.hh
- lib/hnco/functions/jump.cc

5.37 Labs Class Reference

Low autocorrelation binary sequences.

```
#include <hnco/functions/labs.hh>
```

Inheritance diagram for Labs:



Public Member Functions

- [Labs](#) (int n)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

Private Attributes

- `std::vector< int > _sequence`
Binary sequence written using 1 and -1.

5.37.1 Detailed Description

Low autocorrelation binary sequences.

Reference:

S Mertens. 1996. Exhaustive search for low-autocorrelation binary sequences. Journal of Physics A: Mathematical and General 29, 18 (1996), L473.

<http://stacks.iop.org/0305-4470/29/i=18/a=005>

Definition at line 43 of file labs.hh.

The documentation for this class was generated from the following files:

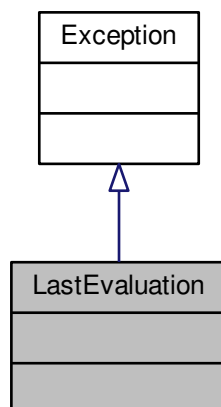
- lib/hnco/functions/labs.hh
- lib/hnco/functions/labs.cc

5.38 LastEvaluation Class Reference

Last evaluation.

```
#include <hnco/exception.hh>
```

Inheritance diagram for LastEvaluation:



5.38.1 Detailed Description

Last evaluation.

Definition at line 79 of file exception.hh.

The documentation for this class was generated from the following file:

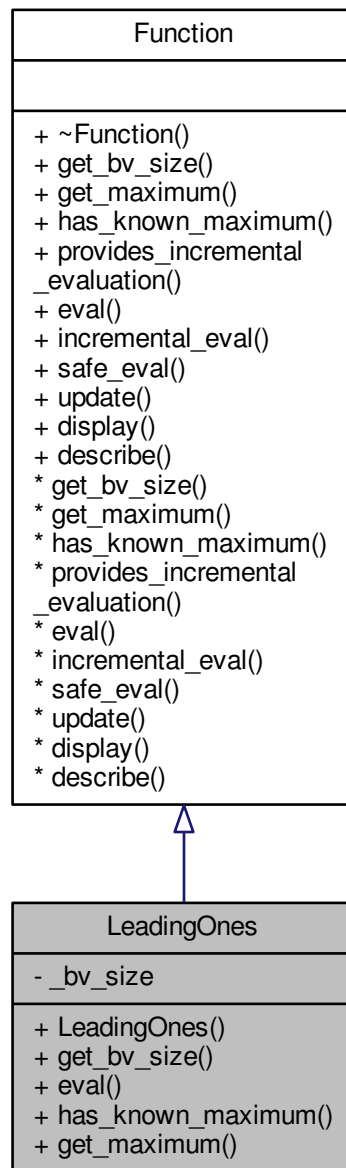
- lib/hnco/exception.hh

5.39 LeadingOnes Class Reference

Leading ones.

```
#include <hnco/functions/theory.hh>
```


Inheritance diagram for LeadingOnes:



Public Member Functions

- [LeadingOnes](#) (int bv_size)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- `bool` [has_known_maximum](#) ()

Check for a known maximum.

- double [get_maximum](#) ()

Get the global maximum.

Private Attributes

- size_t [_bv_size](#)

Bit vector size.

5.39.1 Detailed Description

Leading ones.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 93 of file theory.hh.

5.39.2 Member Function Documentation

5.39.2.1 [get_maximum\(\)](#)

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

[_bv_size](#)

Reimplemented from [Function](#).

Definition at line 117 of file theory.hh.

5.39.2.2 [has_known_maximum\(\)](#)

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 113 of file theory.hh.

The documentation for this class was generated from the following files:

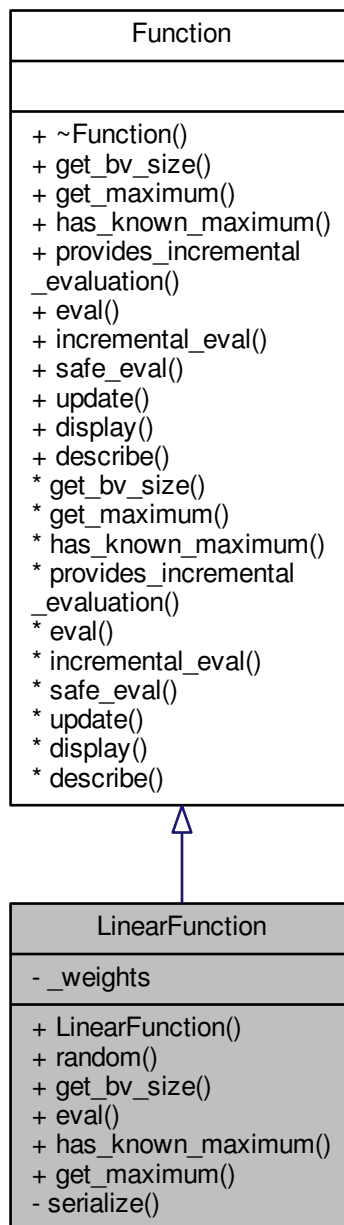
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.40 LinearFunction Class Reference

Linear function.

```
#include <hnco/functions/linear-function.hh>
```

Inheritance diagram for LinearFunction:



Public Member Functions

- [LinearFunction](#) ()

Constructor.

- void [random](#) (int n)

Random instance.

- size_t [get_bv_size](#) ()

Get bit vector size.

- double [eval](#) (const [bit_vector_t](#) &)

Evaluate a bit vector.

- bool [has_known_maximum](#) ()

Check for a known maximum.

- double [get_maximum](#) ()

Get the global maximum.

Private Member Functions

- template<class Archive >
void [serialize](#) (Archive &ar, const unsigned int version)
Serialize.

Private Attributes

- std::vector< double > [_weights](#)
Weights.

Friends

- class **boost::serialization::access**

5.40.1 Detailed Description

Linear function.

Definition at line 40 of file linear-function.hh.

5.40.2 Member Function Documentation

5.40.2.1 [has_known_maximum\(\)](#)

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 76 of file linear-function.hh.

5.40.2.2 random()

```
void random (
    int n )
```

Random instance.

Parameters

n	Size of bit vectors
-----	---------------------

Definition at line 34 of file linear-function.cc.

The documentation for this class was generated from the following files:

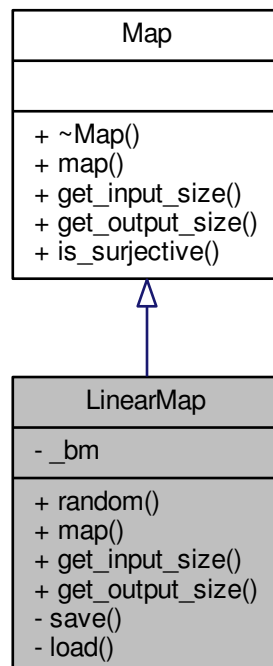
- lib/hnco/functions/linear-function.hh
- lib/hnco/functions/linear-function.cc

5.41 LinearMap Class Reference

Linear map.

```
#include <hnco/map.hh>
```

Inheritance diagram for LinearMap:



Public Member Functions

- void `random` (int n, int m)
Random instance.
- void `map` (const `bit_vector_t` &input, `bit_vector_t` &output)
Map.
- `size_t` `get_input_size` ()
Get input size.
- `size_t` `get_output_size` ()
Get output size.

Private Member Functions

- template<class Archive >
void `save` (Archive &ar, const unsigned int version) const
Save.
- template<class Archive >
void `load` (Archive &ar, const unsigned int version)
Load.

Private Attributes

- `bit_matrix_t` `_bm`
Bit matrix.

Friends

- class `boost::serialization::access`

5.41.1 Detailed Description

Linear map.

A linear map f from Z_2^m to Z_2^n is defined by $f(x) = Ax$, where A is an $m \times n$ bit matrix.

Warning

The class does not reimplement the member function `is_surjective` hence a linear map is always considered not surjective.

Definition at line 197 of file `map.hh`.

The documentation for this class was generated from the following files:

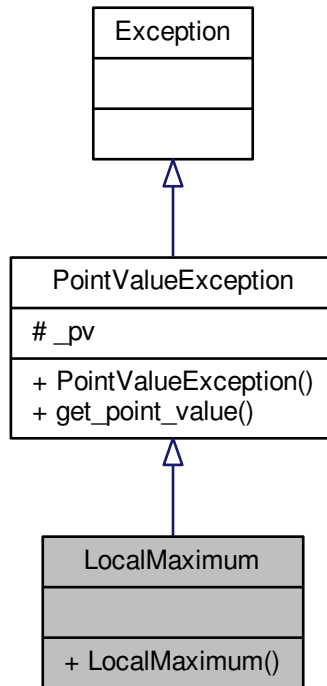
- `lib/hnco/map.hh`
- `lib/hnco/map.cc`

5.42 LocalMaximum Class Reference

Local maximum.

```
#include <hnco/exception.hh>
```

Inheritance diagram for LocalMaximum:



Public Member Functions

- [LocalMaximum](#) (const [point_value_t](#) &pv)
Const.

Additional Inherited Members

5.42.1 Detailed Description

Local maximum.

Definition at line 70 of file `exception.hh`.

The documentation for this class was generated from the following file:

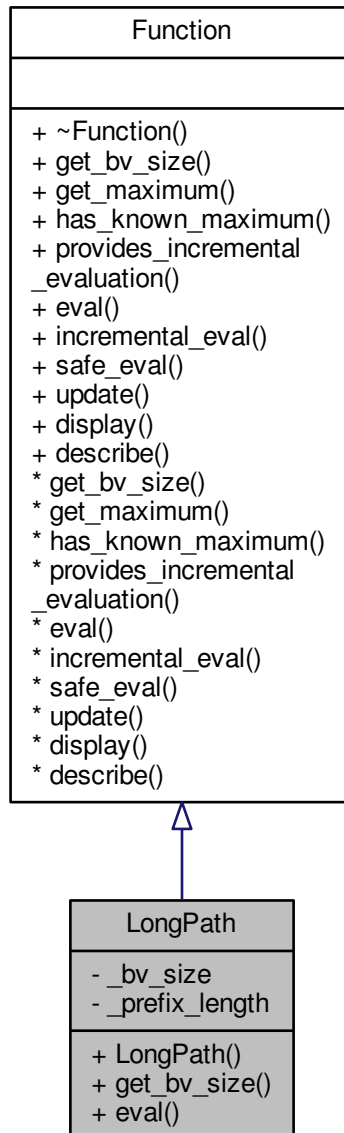
- `lib/hnco/exception.hh`

5.43 LongPath Class Reference

Long path.

```
#include <hnco/functions/long-path.hh>
```

Inheritance diagram for LongPath:



Public Member Functions

- [LongPath](#) (int bv_size, int prefix_length)
Constructor.

- `size_t get_bv_size ()`
Get bit vector size.
- `double eval (const bit_vector_t &)`
Evaluate a bit vector.

Private Attributes

- `size_t _bv_size`
Bit vector size.
- `int _prefix_length`
Prefix length.

5.43.1 Detailed Description

Long path.

Long paths have been introduced by Jeffrey Horn, David E. Goldberg, and Kalyanmoy Deb. Here we follow the definition given by Thomas Jansen (see references below).

As an example, here is the 2-long path of dimension 4:

- 0000
- 0001
- 0011
- 0111
- 1111
- 1101
- 1100

The fitness is increasing along the path. The fitness on the complementary of the path is defined as a linear function pointing to the beginning of the path.

References:

Jeffrey Horn, David E. Goldberg, and Kalyanmoy Deb, "Long Path Problems", PPSN III, 1994.

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 58 of file long-path.hh.

The documentation for this class was generated from the following files:

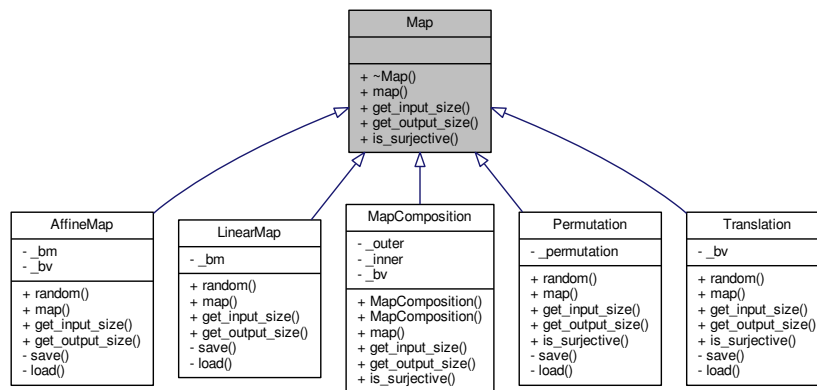
- lib/hnco/functions/long-path.hh
- lib/hnco/functions/long-path.cc

5.44 Map Class Reference

[Map](#).

```
#include <hnco/map.hh>
```

Inheritance diagram for Map:



Public Member Functions

- virtual [~Map](#) ()
Destructor.
- virtual void [map](#) (const [bit_vector_t](#) &input, [bit_vector_t](#) &output)=0
[Map](#).
- virtual size_t [get_input_size](#) ()=0
Get input size.
- virtual size_t [get_output_size](#) ()=0
Get output size.
- virtual bool [is_surjective](#) ()
Check for surjective map.

5.44.1 Detailed Description

[Map](#).

Definition at line 39 of file map.hh.

5.44.2 Member Function Documentation

5.44.2.1 is_surjective()

```
virtual bool is_surjective ( ) [inline], [virtual]
```

Check for surjective map.

Returns

false

Reimplemented in [MapComposition](#), [Permutation](#), and [Translation](#).

Definition at line 59 of file map.hh.

The documentation for this class was generated from the following file:

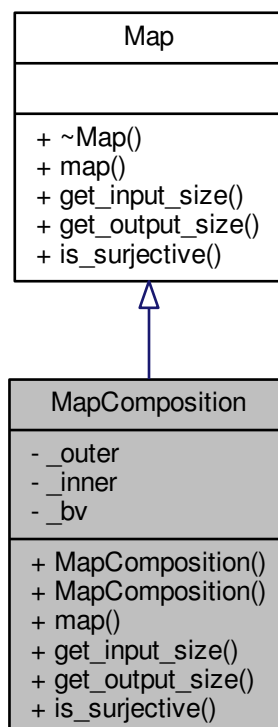
- lib/hnco/map.hh

5.45 MapComposition Class Reference

[Map](#) composition.

```
#include <hnco/map.hh>
```

Inheritance diagram for MapComposition:



Public Member Functions

- [MapComposition](#) ()
Default constructor.
- [MapComposition](#) ([Map](#) *outer, [Map](#) *inner)
Constructor.
- void [map](#) (const [bit_vector_t](#) &input, [bit_vector_t](#) &output)
Map.
- size_t [get_input_size](#) ()
Get input size.
- size_t [get_output_size](#) ()
Get output size.
- bool [is_surjective](#) ()
Check for surjective map.

Private Attributes

- [Map](#) * [_outer](#)
Outer map.
- [Map](#) * [_inner](#)
Inner map.
- [bit_vector_t](#) [_bv](#)
Temporary bit vector.

5.45.1 Detailed Description

[Map](#) composition.

The resulting composition f is defined for all bit vector x by $f(x) = \text{outer}(\text{inner}(x))$.

Definition at line 326 of file map.hh.

5.45.2 Constructor & Destructor Documentation

5.45.2.1 MapComposition()

```
MapComposition (
    Map * outer,
    Map * inner ) [inline]
```

Constructor.

Parameters

<i>outer</i>	outer map
<i>inner</i>	inner map

Precondition

```
outer->get_input_size() == inner->get_output_size()
```

Definition at line 350 of file map.hh.

5.45.3 Member Function Documentation

5.45.3.1 is_surjective()

```
bool is_surjective ( ) [inline], [virtual]
```

Check for surjective map.

Returns

true if both maps are surjective

Reimplemented from [Map](#).

Definition at line 374 of file map.hh.

The documentation for this class was generated from the following file:

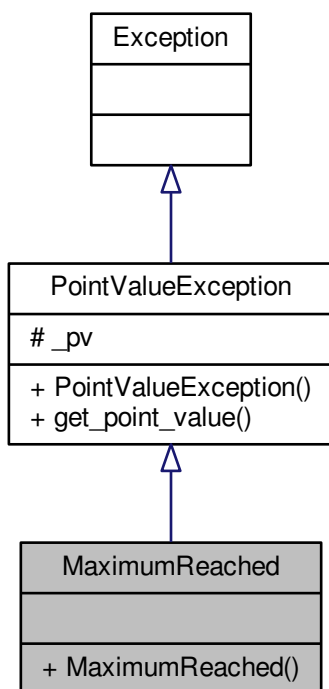
- lib/hnco/map.hh

5.46 MaximumReached Class Reference

Maximum reached.

```
#include <hnco/exception.hh>
```

Inheritance diagram for MaximumReached:



Public Member Functions

- [MaximumReached](#) (const [point_value_t](#) &pv)
Constructor.

Additional Inherited Members

5.46.1 Detailed Description

Maximum reached.

Definition at line 52 of file `exception.hh`.

The documentation for this class was generated from the following file:

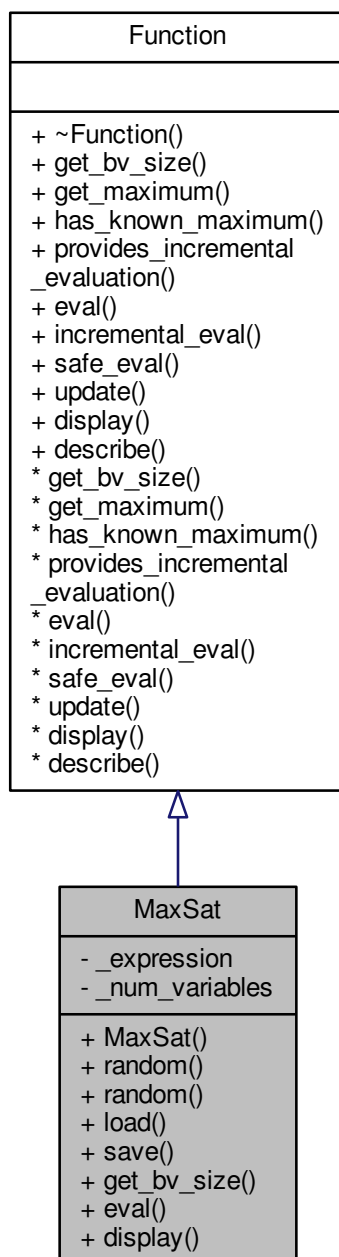
- `lib/hnco/exception.hh`

5.47 MaxSat Class Reference

MAX-SAT.

```
#include <hnco/functions/max-sat.hh>
```

Inheritance diagram for MaxSat:



Public Member Functions

- [MaxSat](#) ()
Default constructor.
- void [random](#) (int n, int k, int c)
Random instance.
- void [random](#) (const [bit_vector_t](#) &solution, int k, int c)
Random instance with satisfiable expression.
- void [load](#) (std::istream &stream)
Load an instance.
- void [save](#) (std::ostream &stream)
Save an instance.
- size_t [get_bv_size](#) ()
Get bit vector size.
- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- void [display](#) (std::ostream &stream)
Display the expression.

Private Attributes

- std::vector< std::vector< int > > [_expression](#)
Expression.
- size_t [_num_variables](#)
Number of variables.

5.47.1 Detailed Description

MAX-SAT.

Reference:

Christos M. Papadimitriou. 1994. Computational complexity. Addison-Wesley, Reading, Massachusetts.

Definition at line 42 of file max-sat.hh.

5.47.2 Member Function Documentation

5.47.2.1 load()

```
void load (
    std::istream & stream )
```

Load an instance.

Exceptions

<i>Error</i>	
--------------	--

Definition at line 134 of file max-sat.cc.

5.47.2.2 random() [1/2]

```
void random (
    int n,
    int k,
    int c )
```

Random instance.

Parameters

<i>n</i>	Size of bit vectors
<i>k</i>	Number of literals per clause
<i>c</i>	Number of clauses

Definition at line 39 of file max-sat.cc.

5.47.2.3 random() [2/2]

```
void random (
    const bit_vector_t & solution,
    int k,
    int c )
```

Random instance with satisfiable expression.

Warning

Since the expression is satisfiable, the maximum of the function is equal to the number of clauses in the expression. However, this information is lost in the save and load cycle as the archive format only manages the expression itself.

Parameters

<i>solution</i>	Solution
<i>k</i>	Number of literals per clause
<i>c</i>	Number of clauses

Definition at line 67 of file max-sat.cc.

5.47.3 Member Data Documentation

5.47.3.1 `_expression`

```
std::vector<std::vector<int> > _expression [private]
```

Expression.

An expression is represented by a vector of clauses. A clause is represented by a vector of literals. A literal is represented by a non null integer; if the integer is positive then the literal is a variable; if it is negative then it is the logical negation of a variable.

Definition at line 52 of file max-sat.hh.

The documentation for this class was generated from the following files:

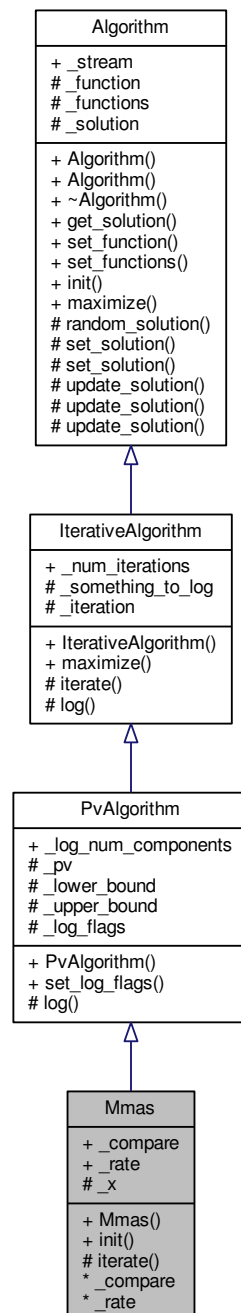
- lib/hnco/functions/max-sat.hh
- lib/hnco/functions/max-sat.cc

5.48 Mmas Class Reference

Max-min ant system.

```
#include <hnco/algorithms/pv/mmas.hh>
```

Inheritance diagram for Mmas:



Public Member Functions

- [Mmas](#) (int n)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- `std::function< bool(double, double)> _compare` = `std::greater_equal<double>()`
Binary operator for comparing evaluations.
- `double _rate`
Learning rate.

Protected Member Functions

- `void iterate ()`
Single iteration.

Protected Attributes

- `bit_vector_t _x`
Candidate solution.

Additional Inherited Members

5.48.1 Detailed Description

Max-min ant system.

Reference:

Thomas Stützle and Holger H. Hoos. 2000. MAX-MIN Ant System. *Future Generation Computer Systems* 16, 8 (2000), 889–914.

Definition at line 41 of file `mmas.hh`.

The documentation for this class was generated from the following files:

- `lib/hnco/algorithms/pv/mmas.hh`
- `lib/hnco/algorithms/pv/mmas.cc`

5.49 Model Class Reference

`Model` of a Boltzmann machine.

```
#include <hnco/algorithms/bm-pbil/model.hh>
```

Public Member Functions

- [Model](#) (int n)
Constructor.
- void [init](#) ()
Initialize.
- void [reset_mc](#) ()
Reset Markov chain.
- void [gibbs_sampler](#) (size_t i)
A Gibbs sampler cycle.
- void [gibbs_sampler_synchronous](#) ()
A synchronous Gibbs sampler.
- const [bit_vector_t](#) & [get_state](#) ()
Get the state of the Gibbs sampler.
- void [update](#) (const [ModelParameters](#) &p, const [ModelParameters](#) &q, double rate)
Update parameters in the direction of p and away from q.
- double [norm_infinite](#) ()
Infinite norm of the parameters.
- double [norm_l1](#) ()
l1 norm of the parameters

Private Attributes

- [ModelParameters](#) [_model_parameters](#)
Model parameters.
- [bit_vector_t](#) [_state](#)
State of the Gibbs sampler.
- [pv_t](#) [_pv](#)
Probability vector for synchronous Gibbs sampling.

5.49.1 Detailed Description

[Model](#) of a Boltzmann machine.

Definition at line 75 of file `model.hh`.

The documentation for this class was generated from the following files:

- `lib/hnco/algorithms/bm-pbil/model.hh`
- `lib/hnco/algorithms/bm-pbil/model.cc`

5.50 ModelParameters Class Reference

Parameters of a Boltzmann machine.

```
#include <hnco/algorithms/bm-pbil/model.hh>
```

Public Member Functions

- [ModelParameters](#) (int n)
Constructor.
- void [init](#) ()
Initialize.
- void [add](#) (const [bit_vector_t](#) &x)
Add a bit_vector_t.
- void [average](#) (int count)
Compute averages.
- void [update](#) (const [ModelParameters](#) &p, const [ModelParameters](#) &q, double rate)
Update parameters in the direction of p and away from q.
- double [norm_infinite](#) ()
Infinite norm of the parameters.
- double [norm_l1](#) ()
l1 norm of the parameters

Private Attributes

- std::vector< std::vector< double > > [_weight](#)
Weights.
- std::vector< double > [_bias](#)
Bias.

Friends

- class **Model**

5.50.1 Detailed Description

Parameters of a Boltzmann machine.

Definition at line 36 of file model.hh.

The documentation for this class was generated from the following files:

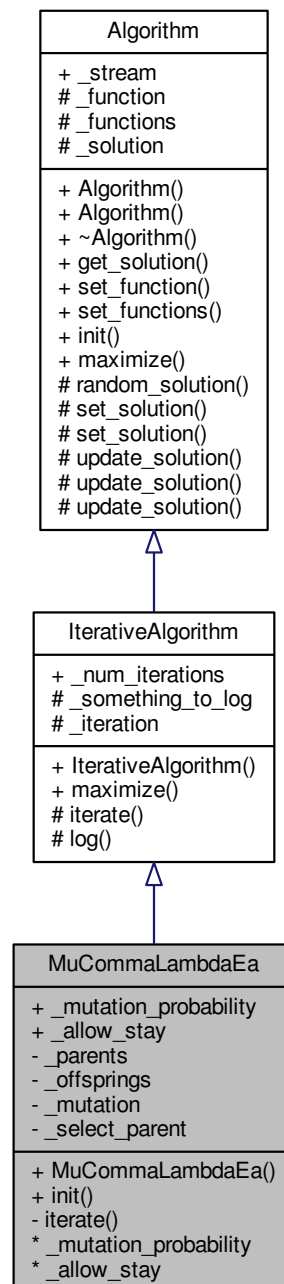
- lib/hnco/algorithms/bm-pbil/model.hh
- lib/hnco/algorithms/bm-pbil/model.cc

5.51 MuCommaLambdaEa Class Reference

(mu, lambda) EA.

```
#include <hnco/algorithms/ea/mu-comma-lambda-ea.hh>
```

Inheritance diagram for MuCommaLambdaEa:



Public Member Functions

- [MuCommaLambdaEa](#) (int n, int mu, int lambda)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- double [_mutation_probability](#)
Mutation probability.
- bool [_allow_stay](#) = false
Allow stay.

Private Member Functions

- void [iterate](#) ()
Single iteration.

Private Attributes

- [Population_parents](#)
Parents.
- [Population_offsprings](#)
Offsprings.
- [neighborhood::BernoulliProcess_mutation](#)
Mutation operator.
- std::uniform_int_distribution< int > [_select_parent](#)
Select parent.

Additional Inherited Members

5.51.1 Detailed Description

(mu, lambda) EA.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 41 of file mu-comma-lambda-ea.hh.

5.51.2 Constructor & Destructor Documentation

5.51.2.1 MuCommaLambdaEa()

```
MuCommaLambdaEa (
    int n,
    int mu,
    int lambda ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
<i>mu</i>	Parent population size
<i>lambda</i>	Offspring population size

Definition at line 67 of file mu-comma-lambda-ea.hh.

5.51.3 Member Data Documentation

5.51.3.1 `_allow_stay`

```
bool _allow_stay = false
```

Allow stay.

In case no mutation occurs allow the current bit vector to stay unchanged.

Definition at line 90 of file mu-comma-lambda-ea.hh.

The documentation for this class was generated from the following files:

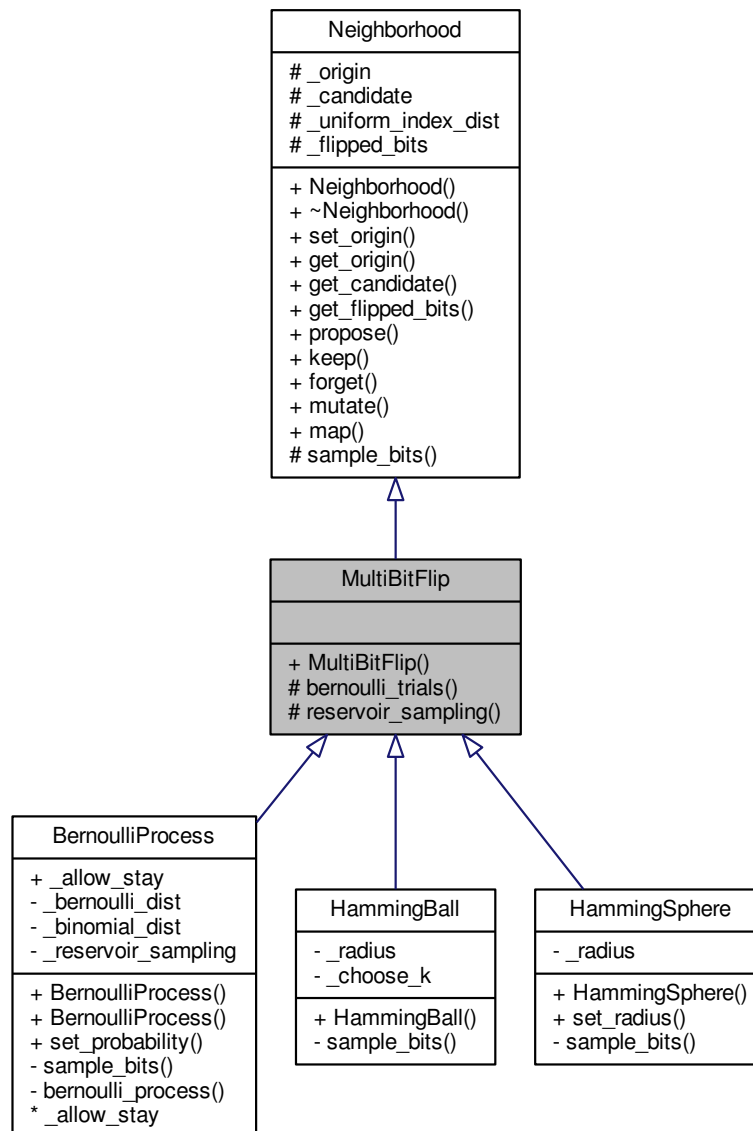
- lib/hnco/algorithms/ea/mu-comma-lambda-ea.hh
- lib/hnco/algorithms/ea/mu-comma-lambda-ea.cc

5.52 MultiBitFlip Class Reference

Multi bit flip.

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for MultiBitFlip:



Public Member Functions

- [MultiBitFlip](#) (int n)

Constructor.

Protected Member Functions

- void [bernoulli_trials](#) (int k)

Sample a given number of bits using Bernoulli trials.

- void [reservoir_sampling](#) (int k)

Sample a given number of bits using resevoir sampling.

Additional Inherited Members

5.52.1 Detailed Description

Multi bit flip.

Definition at line 183 of file neighborhood.hh.

5.52.2 Constructor & Destructor Documentation

5.52.2.1 MultiBitFlip()

```
MultiBitFlip (  
    int n ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
-----	---------------------

Definition at line 206 of file neighborhood.hh.

5.52.3 Member Function Documentation

5.52.3.1 bernoulli_trials()

```
void bernoulli_trials (  
    int k ) [protected]
```

Sample a given number of bits using Bernoulli trials.

Parameters

k	Number of bits to sample
-----	--------------------------

Definition at line 34 of file neighborhood.cc.

5.52.3.2 reservoir_sampling()

```
void reservoir_sampling (  
    int k ) [protected]
```

Sample a given number of bits using resevoir sampling.

Parameters

k	Number of bits to sample
-----	--------------------------

Definition at line 52 of file neighborhood.cc.

The documentation for this class was generated from the following files:

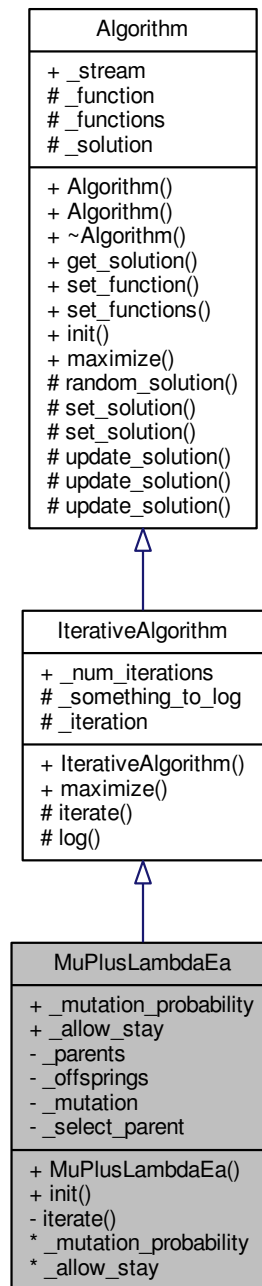
- lib/hnco/neighborhoods/neighborhood.hh
- lib/hnco/neighborhoods/neighborhood.cc

5.53 MuPlusLambdaEa Class Reference

(mu+lambda) EA.

```
#include <hnco/algorithms/ea/mu-plus-lambda-ea.hh>
```

Inheritance diagram for MuPlusLambdaEa:



Public Member Functions

- [MuPlusLambdaEa](#) (int n, int mu, int lambda)

Constructor.

- void [init](#) ()

Initialization.

Public Attributes

Parameters

- double [_mutation_probability](#)
Mutation probability.
- bool [_allow_stay](#) = false
Allow stay.

Private Member Functions

- void [iterate](#) ()
Single iteration.

Private Attributes

- [Population_parents](#)
Parents.
- [Population_offsprings](#)
Offsprings.
- [neighborhood::BernoulliProcess_mutation](#)
Mutation operator.
- [std::uniform_int_distribution< int > _select_parent](#)
Select parent.

Additional Inherited Members

5.53.1 Detailed Description

(mu+lambda) EA.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 40 of file mu-plus-lambda-ea.hh.

5.53.2 Constructor & Destructor Documentation

5.53.2.1 MuPlusLambdaEa()

```
MuPlusLambdaEa (
    int n,
    int mu,
    int lambda ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
<i>mu</i>	Parent population size
<i>lambda</i>	Offspring population size

Definition at line 66 of file mu-plus-lambda-ea.hh.

5.53.3 Member Data Documentation

5.53.3.1 `_allow_stay`

```
bool _allow_stay = false
```

Allow stay.

In case no mutation occurs allow the current bit vector to stay unchanged.

Definition at line 89 of file mu-plus-lambda-ea.hh.

The documentation for this class was generated from the following files:

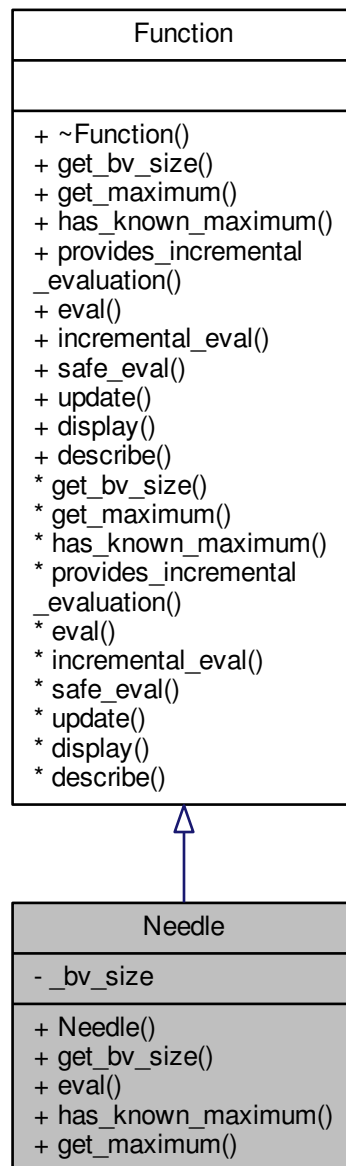
- lib/hnco/algorithms/ea/mu-plus-lambda-ea.hh
- lib/hnco/algorithms/ea/mu-plus-lambda-ea.cc

5.54 Needle Class Reference

[Needle](#) in a haystack.

```
#include <hnco/functions/theory.hh>
```


Inheritance diagram for Needle:



Public Member Functions

- [Needle](#) (int bv_size)
Constructor.
- size_t [get_bv_size](#) ()
Get bit vector size.
- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- bool [has_known_maximum](#) ()

Check for a known maximum.

- double [get_maximum](#) ()

Get the global maximum.

Private Attributes

- size_t [_bv_size](#)

Bit vector size.

5.54.1 Detailed Description

[Needle](#) in a haystack.

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 129 of file theory.hh.

5.54.2 Member Function Documentation

5.54.2.1 [get_maximum](#)()

```
double get\_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

1

Reimplemented from [Function](#).

Definition at line 153 of file theory.hh.

5.54.2.2 [has_known_maximum](#)()

```
bool has\_known\_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 149 of file theory.hh.

The documentation for this class was generated from the following files:

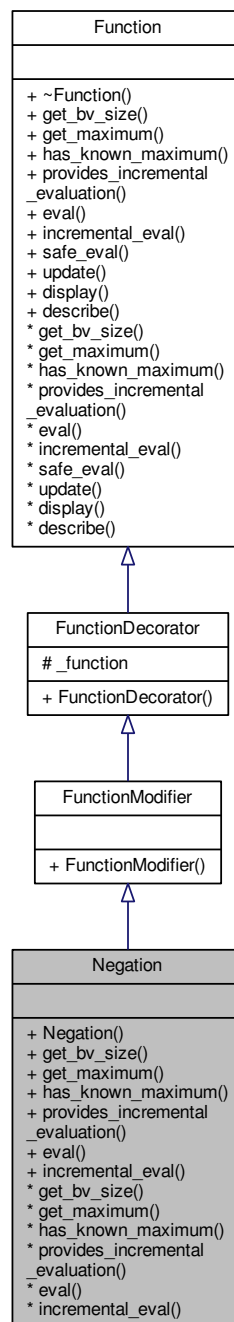
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.55 Negation Class Reference

Negation.

```
#include <hnco/functions/decorators/function-modifier.hh>
```

Inheritance diagram for Negation:



Public Member Functions

- [Negation](#) ([Function](#) *function)
Constructor.

Information about the function

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [get_maximum](#) ()
Get the global maximum.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.
- `bool` [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.

Evaluation

- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- `double` [incremental_eval](#) (const [bit_vector_t](#) &x, double value, const [hnco::sparse_bit_vector_t](#) &flipped↔
_bits)
Incremental evaluation.

Additional Inherited Members

5.55.1 Detailed Description

[Negation](#).

Use cases:

- for algorithms which minimize rather than maximize a function
- for functions one wishes to minimize
- when minimization is needed inside an algorithm

Definition at line 58 of file `function-modifier.hh`.

5.55.2 Member Function Documentation

5.55.2.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Exceptions

<i>Error</i>	
--------------	--

Reimplemented from [Function](#).

Definition at line 76 of file function-modifier.hh.

5.55.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

false

Reimplemented from [Function](#).

Definition at line 80 of file function-modifier.hh.

5.55.2.3 provides_incremental_evaluation()

```
bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

true

Reimplemented from [Function](#).

Definition at line 85 of file function-modifier.hh.

The documentation for this class was generated from the following files:

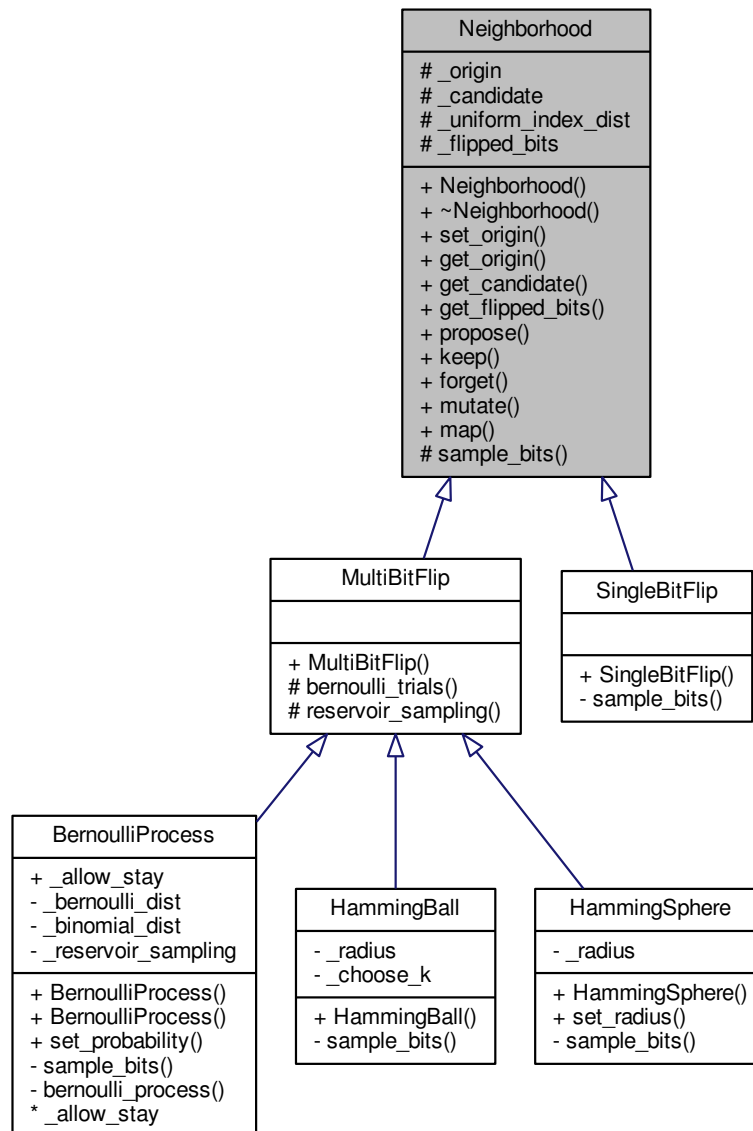
- lib/hnco/functions/decorators/function-modifier.hh
- lib/hnco/functions/decorators/function-modifier.cc

5.56 Neighborhood Class Reference

[Neighborhood](#).

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for Neighborhood:



Public Member Functions

- [Neighborhood](#) (int n)
Constructor.
- virtual [~Neighborhood](#) ()

- Destructor.*
- virtual void [set_origin](#) (const [bit_vector_t](#) &x)
- Set the origin.*
- virtual const [bit_vector_t](#) & [get_origin](#) ()
- Get the origin.*
- virtual const [bit_vector_t](#) & [get_candidate](#) ()
- Get the candidate bit vector.*
- virtual const [sparse_bit_vector_t](#) & [get_flipped_bits](#) ()
- Get flipped bits.*
- virtual void [propose](#) ()
- Propose a candidate bit vector.*
- virtual void [keep](#) ()
- Keep the candidate bit vector.*
- virtual void [forget](#) ()
- Forget the candidate bit vector.*
- virtual void [mutate](#) ([bit_vector_t](#) &bv)
- Mutate.*
- virtual void [map](#) (const [bit_vector_t](#) &input, [bit_vector_t](#) &output)
- Map.*

Protected Member Functions

- virtual void [sample_bits](#) ()=0
- Sample bits.*

Protected Attributes

- [bit_vector_t _origin](#)
- Origin of the neighborhood.*
- [bit_vector_t _candidate](#)
- candidate bit vector*
- `std::uniform_int_distribution< int > _uniform_index_dist`
- Uniform index distribution.*
- [sparse_bit_vector_t _flipped_bits](#)
- Flipped bits.*

5.56.1 Detailed Description

[Neighborhood](#).

A neighborhood maintains two points, `_origin` and `_candidate`. They are initialized in the same state by `set_origin`. A [Neighborhood](#) class must implement the member function `sample_bits` which samples the bits to flip in `_origin` to get a `_candidate`. The following member functions take care of the modifications:

- `propose`: flip `_candidate`
- `keep`: flip `_origin`
- `forget` flip `_candidate`

After `keep` or `forget`, `_origin` and `_candidate` are in the same state again.

A [Neighborhood](#) class can also behave as a mutation operator through the member functions `mutate` and `map`.

Definition at line 61 of file `neighborhood.hh`.

5.56.2 Constructor & Destructor Documentation

5.56.2.1 Neighborhood()

```
Neighborhood (
    int n ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
----------	---------------------

Definition at line 86 of file neighborhood.hh.

5.56.3 Member Function Documentation

5.56.3.1 map()

```
virtual void map (
    const bit_vector_t & input,
    bit_vector_t & output ) [inline], [virtual]
```

Map.

The output bit vector is a mutated version of the input bit vector.

Parameters

<i>input</i>	Input bit vector
<i>output</i>	Output bit vector

Definition at line 148 of file neighborhood.hh.

5.56.3.2 mutate()

```
virtual void mutate (
    bit_vector_t & bv ) [inline], [virtual]
```

Mutate.

In-place mutation of the bit vector.

Parameters

<i>bv</i>	Bit vector to mutate
-----------	----------------------

Definition at line 134 of file neighborhood.hh.

The documentation for this class was generated from the following file:

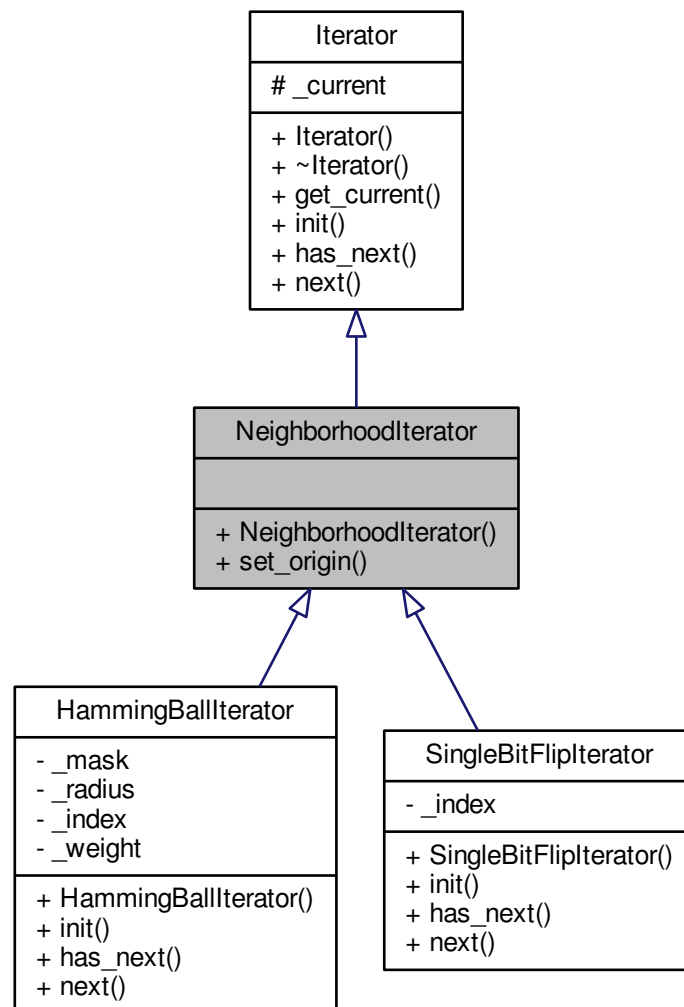
- lib/hnco/neighborhoods/neighborhood.hh

5.57 NeighborhoodIterator Class Reference

[Neighborhood](#) iterator.

```
#include <hnco/neighborhoods/neighborhood-iterator.hh>
```

Inheritance diagram for NeighborhoodIterator:



Public Member Functions

- [NeighborhoodIterator](#) (int n)
Constructor.
- virtual void [set_origin](#) (const [bit_vector_t](#) &x)
Set origin.

Additional Inherited Members

5.57.1 Detailed Description

[Neighborhood](#) iterator.

Definition at line 38 of file neighborhood-iterator.hh.

5.57.2 Constructor & Destructor Documentation

5.57.2.1 NeighborhoodIterator()

```
NeighborhoodIterator (  
    int n ) [inline]
```

Constructor.

Parameters

<i>n</i>	Size of bit vectors
----------	---------------------

Definition at line 49 of file neighborhood-iterator.hh.

The documentation for this class was generated from the following files:

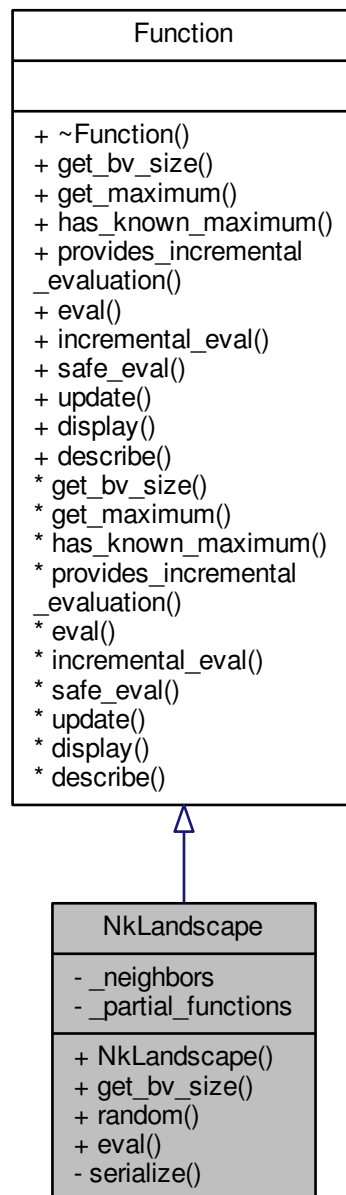
- lib/hnco/neighborhoods/neighborhood-iterator.hh
- lib/hnco/neighborhoods/neighborhood-iterator.cc

5.58 NkLandscape Class Reference

NK landscape.

```
#include <hnco/functions/nk-landscape.hh>
```

Inheritance diagram for NkLandscape:



Public Member Functions

- [NkLandscape](#) ()
Default constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `void` [random](#) (int n, int k, double stddev)
Random instance.

- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.

Private Member Functions

- template<class Archive >
void `serialize` (Archive &ar, const unsigned int version)
Serialize.

Private Attributes

- `std::vector< std::vector< int > > _neighbors`
Bit neighbors.
- `std::vector< std::vector< double > > _partial_functions`
Partial functions.

Friends

- class `boost::serialization::access`

5.58.1 Detailed Description

NK landscape.

Reference:

S. A. Kauffman. 1993. The origins of order: self-organisation and selection in evolution. Oxford University Press.

Definition at line 47 of file nk-landscape.hh.

5.58.2 Member Function Documentation

5.58.2.1 `random()`

```
void random (
    int n,
    int k,
    double stddev )
```

Random instance.

Parameters

<i>n</i>	Size of bit vector
<i>k</i>	Number of neighbors of each bit
<i>stddev</i>	Standard deviation of the values of the partial functions

Definition at line 33 of file nk-landscape.cc.

The documentation for this class was generated from the following files:

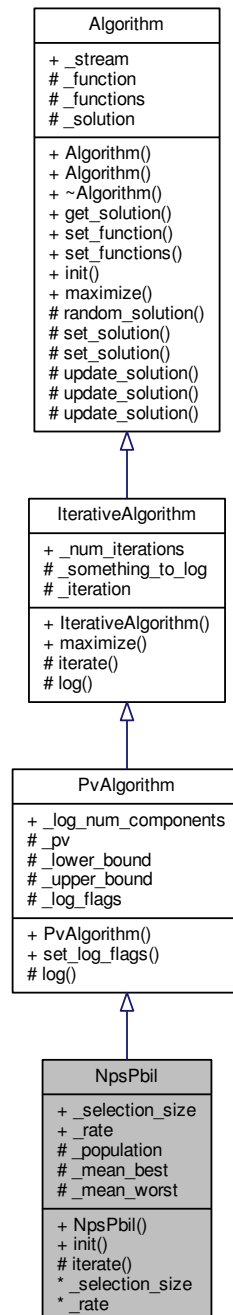
- lib/hnco/functions/nk-landscape.hh
- lib/hnco/functions/nk-landscape.cc

5.59 NpsPbil Class Reference

Population-based incremental learning with negative and positive selection.

```
#include <hnco/algorithms/pv/nps-pbil.hh>
```

Inheritance diagram for NpsPbil:



Public Member Functions

- [NpsPbil](#) (int n, int population_size)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- `int _selection_size = 1`
Selection size.
- `double _rate = 1e-3`
Learning rate.

Protected Member Functions

- `void iterate ()`
Single iteration.

Protected Attributes

- `Population _population`
Population.
- `pv_t _mean_best`
Mean of best individuals.
- `pv_t _mean_worst`
Mean of worst individuals.

Additional Inherited Members

5.59.1 Detailed Description

Population-based incremental learning with negative and positive selection.

Reference:

Arnaud Berny. 2001. Extending selection learning toward fixed-length d-ary strings. In Artificial Evolution (Lecture Notes in Computer Science), P. Collet and others (Eds.). Springer, Le Creusot.

Definition at line 41 of file nps-pbil.hh.

The documentation for this class was generated from the following files:

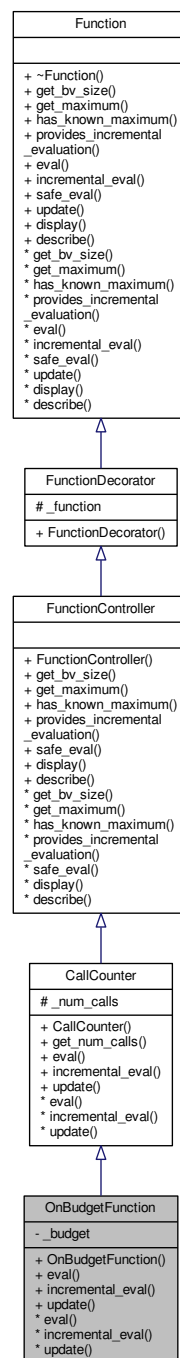
- `lib/hnco/algorithms/pv/nps-pbil.hh`
- `lib/hnco/algorithms/pv/nps-pbil.cc`

5.60 OnBudgetFunction Class Reference

[CallCounter](#) with a limited number of evaluations.

```
#include <hnco/functions/decorators/function-controller.hh>
```

Inheritance diagram for OnBudgetFunction:



Public Member Functions

- [OnBudgetFunction](#) ([Function](#) *function, int budget)
Constructor.

Evaluation

- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- double [incremental_eval](#) (const [bit_vector_t](#) &x, double value, const [hnco::sparse_bit_vector_t](#) &flipped↔
_bits)
Incremental evaluation.
- void [update](#) (const [bit_vector_t](#) &x, double value)
Update after a safe evaluation.

Private Attributes

- int [_budget](#)
Budget.

Additional Inherited Members

5.60.1 Detailed Description

[CallCounter](#) with a limited number of evaluations.

Definition at line 299 of file function-controller.hh.

5.60.2 Member Function Documentation

5.60.2.1 [eval\(\)](#)

```
double eval (
    const bit\_vector\_t & x ) [virtual]
```

Evaluate a bit vector.

Exceptions

<i>LastEvaluation</i>	
-----------------------	--

Reimplemented from [CallCounter](#).

Definition at line 121 of file function-controller.cc.

5.60.2.2 incremental_eval()

```
double incremental_eval (
    const bit_vector_t & x,
    double value,
    const hnco::sparse_bit_vector_t & flipped_bits ) [virtual]
```

Incremental evaluation.

Exceptions

<i>LastEvaluation</i>	
-----------------------	--

Reimplemented from [CallCounter](#).

Definition at line 132 of file function-controller.cc.

5.60.2.3 update()

```
void update (
    const bit_vector_t & x,
    double value ) [virtual]
```

Update after a safe evaluation.

Exceptions

<i>LastEvaluation</i>	
-----------------------	--

Reimplemented from [CallCounter](#).

Definition at line 143 of file function-controller.cc.

The documentation for this class was generated from the following files:

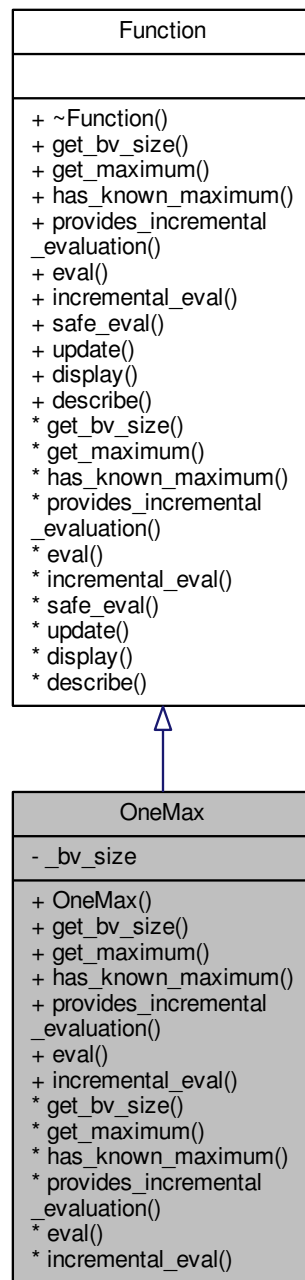
- lib/hnco/functions/decorators/function-controller.hh
- lib/hnco/functions/decorators/function-controller.cc

5.61 OneMax Class Reference

[OneMax](#).

```
#include <hnco/functions/theory.hh>
```

Inheritance diagram for OneMax:



Public Member Functions

- [OneMax](#) (int bv_size)
Constructor.

Information about the function

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [get_maximum](#) ()
Get the global maximum.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.
- `bool` [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.

Evaluation

- `double` [eval](#) (const `bit_vector_t` &)
Evaluate a bit vector.
- `double` [incremental_eval](#) (const `bit_vector_t` &x, double v, const `hnco::sparse_bit_vector_t` &flipped_bits)
Incremental evaluation.

Private Attributes

- `size_t` [_bv_size](#)
Bit vector size.

5.61.1 Detailed Description

[OneMax](#).

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 36 of file `theory.hh`.

5.61.2 Member Function Documentation

5.61.2.1 [get_maximum\(\)](#)

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

`_bv_size`

Reimplemented from [Function](#).

Definition at line 57 of file `theory.hh`.

5.61.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 61 of file theory.hh.

5.61.2.3 provides_incremental_evaluation()

```
bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

true

Reimplemented from [Function](#).

Definition at line 66 of file theory.hh.

The documentation for this class was generated from the following files:

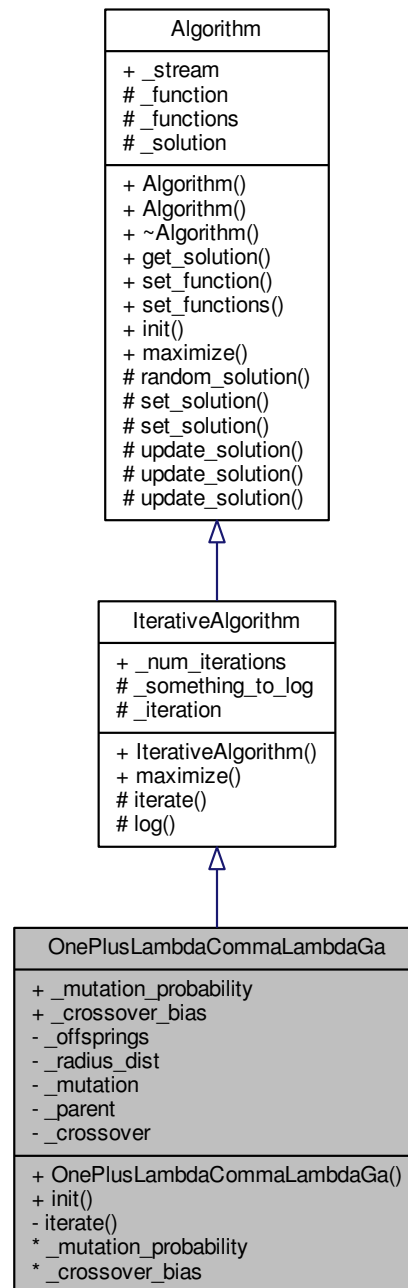
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.62 OnePlusLambdaCommaLambdaGa Class Reference

(1+(lambda, lambda)) genetic algorithm.

```
#include <hnco/algorithms/ea/one-plus-lambda-comma-lambda-ga.hh>
```

Inheritance diagram for OnePlusLambdaCommaLambdaGa:



Public Member Functions

- [OnePlusLambdaCommaLambdaGa](#) (int n, int lambda)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- double [_mutation_probability](#)
Mutation probability.
- double [_crossover_bias](#)
Crossover bias.

Private Member Functions

- void [iterate](#) ()
Single iteration.

Private Attributes

- [Population_offsprings](#)
Offsprings.
- `std::binomial_distribution< int > _radius_dist`
Radius distribution.
- [neighborhood::HammingSphere_mutation](#)
Mutation operator.
- [bit_vector_t _parent](#)
Parent.
- [BiasedCrossover_crossover](#)
Biased crossover.

Additional Inherited Members

5.62.1 Detailed Description

(1+(lambda, lambda)) genetic algorithm.

Reference:

Benjamin Doerr, Carola Doerr, and Franziska Ebel. 2015. From black-box complexity to designing new genetic algorithms. Theoretical Computer Science 567 (2015), 87–104.

Definition at line 49 of file one-plus-lambda-comma-lambda-ga.hh.

5.62.2 Constructor & Destructor Documentation

5.62.2.1 OnePlusLambdaCommaLambdaGa()

```
OnePlusLambdaCommaLambdaGa (
    int n,
    int lambda ) [inline]
```

Constructor.

By default, `_mutation_probability` is set to `lambda / n` and `_crossover_bias` to `1 / lambda`.

Parameters

<i>n</i>	Size of bit vectors
<i>lambda</i>	Offspring population size

Definition at line 80 of file one-plus-lambda-comma-lambda-ga.hh.

The documentation for this class was generated from the following files:

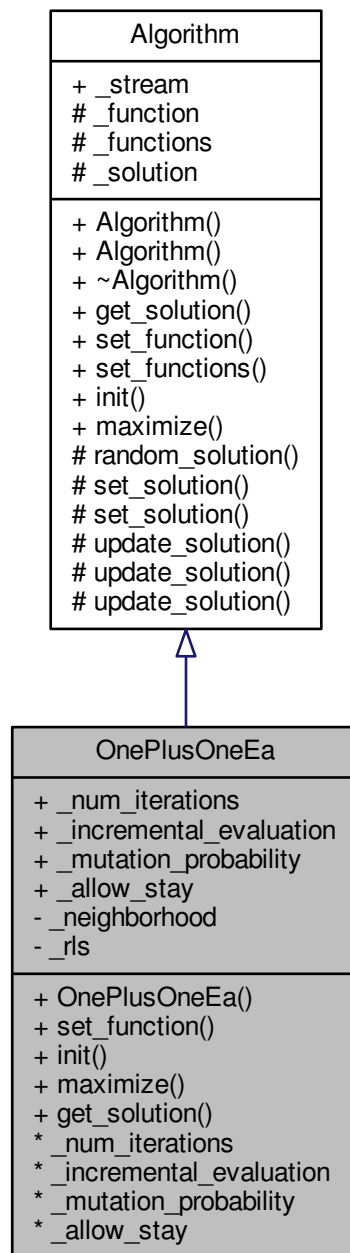
- lib/hnco/algorithms/ea/one-plus-lambda-comma-lambda-ga.hh
- lib/hnco/algorithms/ea/one-plus-lambda-comma-lambda-ga.cc

5.63 OnePlusOneEa Class Reference

(1+1) EA.

```
#include <hnco/algorithms/ea/one-plus-one-ea.hh>
```


Inheritance diagram for OnePlusOneEa:



Public Member Functions

- [OnePlusOneEa](#) (int n)
Constructor.
- void [set_function](#) (function::Function *function)
Set function.
- void [init](#) ()

- Initialization.*
- void [maximize](#) ()
- Maximize.*
- const [point_value_t](#) & [get_solution](#) ()
- Solution.*

Public Attributes

Parameters

- int [_num_iterations](#) = 0
- Number of iterations.*
- bool [_incremental_evaluation](#) = false
- Incremental evaluation.*
- double [_mutation_probability](#)
- Mutation probability.*
- bool [_allow_stay](#) = false
- Allow stay.*

Private Attributes

- [neighborhood::BernoulliProcess](#) [_neighborhood](#)
- Neighborhood.*
- [RandomLocalSearch](#) [_rls](#)
- Random local search.*

Additional Inherited Members

5.63.1 Detailed Description

(1+1) EA.

(1+1) EA is implemented as a [RandomLocalSearch](#) with a [BernoulliProcess](#) neighborhood and infinite patience. Thus it does derive from [IterativeAlgorithm](#).

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 44 of file one-plus-one-ea.hh.

5.63.2 Constructor & Destructor Documentation

5.63.2.1 OnePlusOneEa()

```
OnePlusOneEa (
    int n ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
-----	---------------------

`_mutation_probability` is initialized to $1 / n$.

Definition at line 61 of file `one-plus-one-ea.hh`.

5.63.3 Member Data Documentation

5.63.3.1 `_allow_stay`

```
bool _allow_stay = false
```

Allow stay.

In case no mutation occurs allow the current bit vector to stay unchanged.

Definition at line 107 of file `one-plus-one-ea.hh`.

5.63.3.2 `_num_iterations`

```
int _num_iterations = 0
```

Number of iterations.

`_num_iterations <= 0` means indefinite

Definition at line 94 of file `one-plus-one-ea.hh`.

The documentation for this class was generated from the following file:

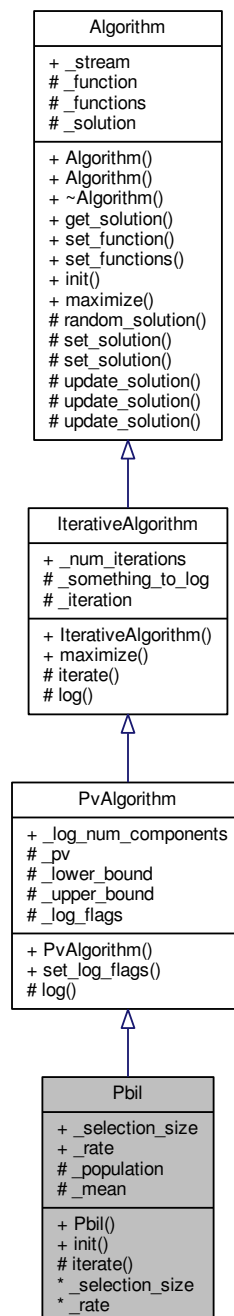
- `lib/hnco/algorithms/ea/one-plus-one-ea.hh`

5.64 Pbil Class Reference

Population-based incremental learning.

```
#include <hnco/algorithms/pv/pbil.hh>
```

Inheritance diagram for Pbil:



Public Member Functions

- `Pbil` (int n, int population_size)
Constructor.
- void `init` ()
Initialization.

Public Attributes

Parameters

- int `_selection_size` = 1
Selection size.
- double `_rate` = 1e-3
Learning rate.

Protected Member Functions

- void `iterate` ()
Single iteration.

Protected Attributes

- `Population _population`
Population.
- `pv_t _mean`
Mean of selected bit vectors.

Additional Inherited Members

5.64.1 Detailed Description

Population-based incremental learning.

Reference:

S. Baluja and R. Caruana. 1995. Removing the genetics from the standard genetic algorithm. In Proceedings of the 12th Annual Conference on Machine Learning. 38–46.

Definition at line 40 of file `pbil.hh`.

The documentation for this class was generated from the following files:

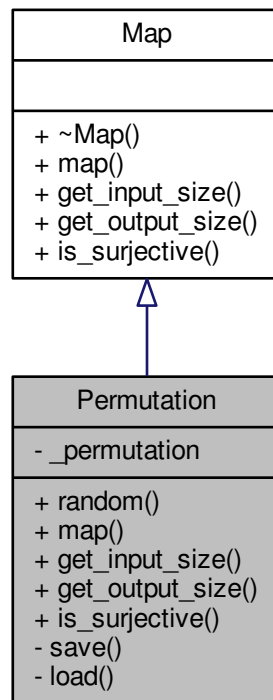
- `lib/hnco/algorithms/pv/pbil.hh`
- `lib/hnco/algorithms/pv/pbil.cc`

5.65 Permutation Class Reference

[Permutation.](#)

```
#include <hnco/map.hh>
```

Inheritance diagram for Permutation:



Public Member Functions

- void [random](#) (int n)
Random instance.
- void [map](#) (const [bit_vector_t](#) &input, [bit_vector_t](#) &output)
Map.
- size_t [get_input_size](#) ()
Get input size.
- size_t [get_output_size](#) ()
Get output size.
- bool [is_surjective](#) ()
Check for surjective map.

Private Member Functions

- `template<class Archive >`
void [save](#) (Archive &ar, const unsigned int version) const
Save.
- `template<class Archive >`
void [load](#) (Archive &ar, const unsigned int version)
Load.

Private Attributes

- [permutation_t_permutation](#)
Permutation.

Friends

- class `boost::serialization::access`

5.65.1 Detailed Description

[Permutation.](#)

A permutation is a linear map f from Z_2^n to itself defined by $f(x) = y$, where $y_i = x_{\sigma_i}$ and σ is a permutation of $0, 1, \dots, n - 1$.

Definition at line 132 of file map.hh.

5.65.2 Member Function Documentation

5.65.2.1 `is_surjective()`

```
bool is_surjective ( ) [inline], [virtual]
```

Check for surjective map.

Returns

true

Reimplemented from [Map](#).

Definition at line 183 of file map.hh.

The documentation for this class was generated from the following files:

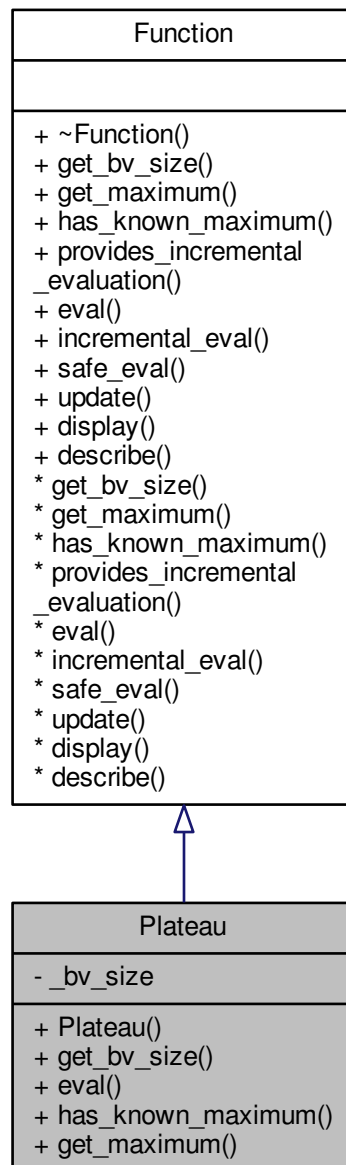
- lib/hnco/map.hh
- lib/hnco/map.cc

5.66 Plateau Class Reference

[Plateau](#).

```
#include <hnco/functions/theory.hh>
```

Inheritance diagram for Plateau:



Public Member Functions

- [Plateau](#) (int bv_size)

Constructor.

- `size_t get_bv_size ()`
Get bit vector size.
- `double eval (const bit_vector_t &)`
Evaluate a bit vector.
- `bool has_known_maximum ()`
Check for a known maximum.
- `double get_maximum ()`
Get the global maximum.

Private Attributes

- `size_t _bv_size`
Bit vector size.

5.66.1 Detailed Description

[Plateau](#).

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 239 of file theory.hh.

5.66.2 Member Function Documentation

5.66.2.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

`_bv_size + 2`

Reimplemented from [Function](#).

Definition at line 263 of file theory.hh.

5.66.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 259 of file theory.hh.

The documentation for this class was generated from the following files:

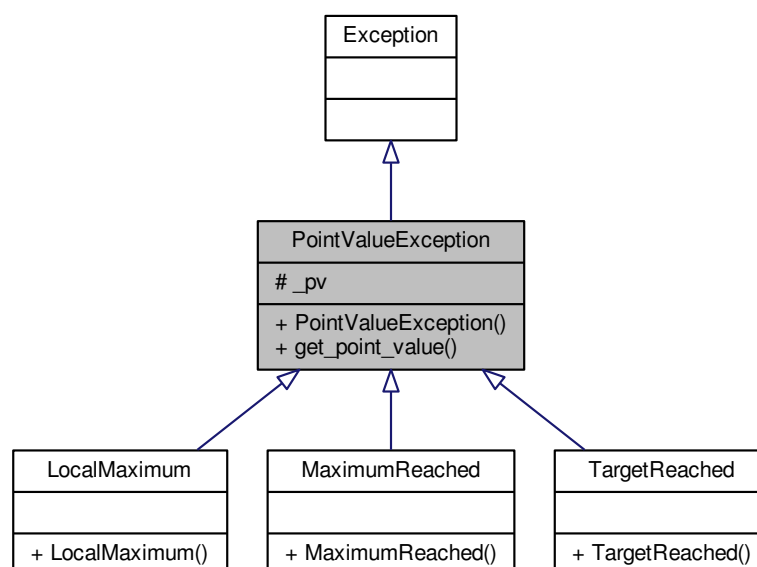
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.67 PointValueException Class Reference

Point-value exception.

```
#include <hnco/exception.hh>
```

Inheritance diagram for PointValueException:



Public Member Functions

- [PointValueException](#) (const [point_value_t](#) &pv)
Constructor.
- const [point_value_t](#) & [get_point_value](#) () const
Get point-value.

Protected Attributes

- [point_value_t _pv](#)
Point-value.

5.67.1 Detailed Description

Point-value exception.

Definition at line 38 of file exception.hh.

The documentation for this class was generated from the following file:

- lib/hnco/exception.hh

5.68 Population Class Reference

[Population](#).

```
#include <hnco/algorithms/population.hh>
```

Inheritance diagram for Population:



Public Types

- `typedef std::pair< size_t, double > index_value_t`

Index-value type.

Public Member Functions

- `Population` (int population_size, int n)
Constructor.
- `std::size_t size` () const
Size.
- `void random` ()
Initialize the population with random bit vectors.
- `bit_vector_t & get_bv` (int i)
Get a bit vector.
- `const bit_vector_t & get_bv` (int i) const
Get a bit vector.

Get sorted bit vectors

- `const bit_vector_t & get_best_bv` (int i) const
Get best bit vector.
- `const bit_vector_t & get_best_bv` () const
Get best bit vector.
- `const bit_vector_t & get_worst_bv` (int i) const
Get worst bit vector.

Get sorted values

- `double get_best_value` (int i) const
Get best value.
- `double get_best_value` () const
Get best value.

Evaluation and sorting

- `void eval` (function::Function *function)
Evaluate the population.
- `void eval` (const std::vector< function::Function *> &functions)
Parallel evaluation of the population.
- `void sort` ()
Sort the lookup table.
- `void partial_sort` (int selection_size)
Partially sort the lookup table.

Selection

- `void plus_selection` (const `Population` &offsprings)
Plus selection.
- `void comma_selection` (const `Population` &offsprings)
Comma selection.

Public Attributes

- `std::function< bool(const index_value_t &, const index_value_t &)> _compare`
Binary operator for comparing index-value pairs.

Protected Attributes

- `std::vector< bit_vector_t > _bvs`
Bit vectors.
- `std::vector< index_value_t > _lookup`
Lookup table.

5.68.1 Detailed Description

[Population](#).

Definition at line 35 of file `population.hh`.

5.68.2 Member Function Documentation

5.68.2.1 `comma_selection()`

```
void comma_selection (
    const Population & offsprings )
```

Comma selection.

Precondition

Offspring population must be sorted.

Warning

The function does not break ties randomly as it should.

Definition at line 108 of file `population.cc`.

5.68.2.2 `get_best_bv()` [1/2]

```
const bit\_vector\_t& get_best_bv (
    int i ) const [inline]
```

Get best bit vector.

Parameters

<i>i</i>	Index in the sorted population
----------	--------------------------------

Precondition

The population must be sorted.

Definition at line 89 of file population.hh.

5.68.2.3 get_best_bv() [2/2]

```
const bit_vector_t& get_best_bv ( ) const [inline]
```

Get best bit vector.

Precondition

The population must be sorted.

Definition at line 95 of file population.hh.

5.68.2.4 get_best_value() [1/2]

```
double get_best_value (
    int i ) const [inline]
```

Get best value.

Parameters

<i>i</i>	Index in the sorted population
----------	--------------------------------

Precondition

The population must be sorted.

Definition at line 118 of file population.hh.

5.68.2.5 get_best_value() [2/2]

```
double get_best_value ( ) const [inline]
```

Get best value.

Precondition

The population must be sorted.

Definition at line 124 of file population.hh.

5.68.2.6 get_worst_bv()

```
const bit_vector_t& get_worst_bv (
    int i ) const [inline]
```

Get worst bit vector.

Parameters

<i>i</i>	Index in the sorted population
----------	--------------------------------

Precondition

The population must be sorted.

Definition at line 103 of file population.hh.

5.68.2.7 plus_selection()

```
void plus_selection (
    const Population & offsprings )
```

Plus selection.

Precondition

Both populations must be sorted.

Warning

The function does not break ties randomly as it should.

Definition at line 89 of file population.cc.

5.68.3 Member Data Documentation

5.68.3.1 _compare

```
std::function<bool(const index_value_t&, const index_value_t&)> _compare
```

Initial value:

```
=
[] (const index_value_t& a, const index_value_t& b) { return a.second > b.
second; }
```

Binary operator for comparing index-value pairs.

Definition at line 43 of file population.hh.

5.68.3.2 `_lookup`

```
std::vector<index_value_t> _lookup [protected]
```

Lookup table.

Let `p` be of type `std::pair<size_t, double>`. Then `p.first` is the bv index in the unsorted population whereas `p.second` is the bv value.

Definition at line 57 of file `population.hh`.

The documentation for this class was generated from the following files:

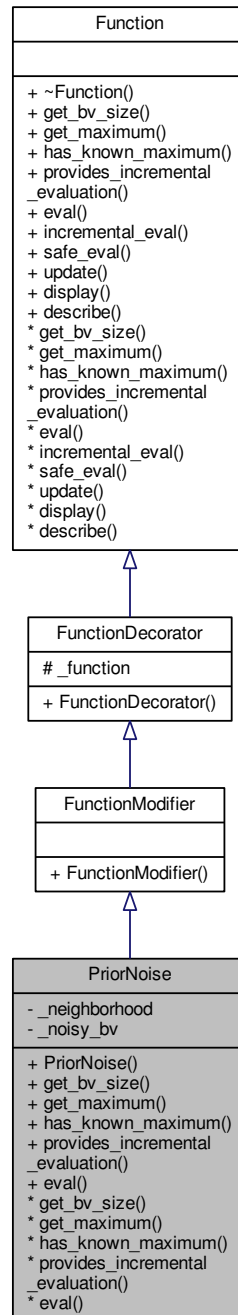
- `lib/hnco/algorithms/population.hh`
- `lib/hnco/algorithms/population.cc`

5.69 PriorNoise Class Reference

Prior noise.

```
#include <hnco/functions/decorators/prior-noise.hh>
```

Inheritance diagram for PriorNoise:



Public Member Functions

- [PriorNoise](#) ([Function](#) *fn, [neighborhood::Neighborhood](#) *nh)
Constructor.

Information about the function

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [get_maximum](#) ()
Get the global maximum.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.
- `bool` [provides_incremental_evaluation](#) ()
Check whether the function provides incremental evaluation.

Evaluation

- `double` [eval](#) (const `bit_vector_t` &)
Evaluate a bit vector.

Private Attributes

- `neighborhood::Neighborhood` * [_neighborhood](#)
Neighborhood.
- `bit_vector_t` [_noisy_bv](#)
Noisy bit vector.

Additional Inherited Members

5.69.1 Detailed Description

Prior noise.

Definition at line 35 of file prior-noise.hh.

5.69.2 Member Function Documentation

5.69.2.1 [get_maximum](#)()

```
double get\_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Delegation is questionable here.

Reimplemented from [Function](#).

Definition at line 67 of file prior-noise.hh.

5.69.2.2 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Delegation is questionable here.

Reimplemented from [Function](#).

Definition at line 73 of file prior-noise.hh.

5.69.2.3 provides_incremental_evaluation()

```
bool provides_incremental_evaluation ( ) [inline], [virtual]
```

Check whether the function provides incremental evaluation.

Returns

false

Reimplemented from [Function](#).

Definition at line 77 of file prior-noise.hh.

The documentation for this class was generated from the following files:

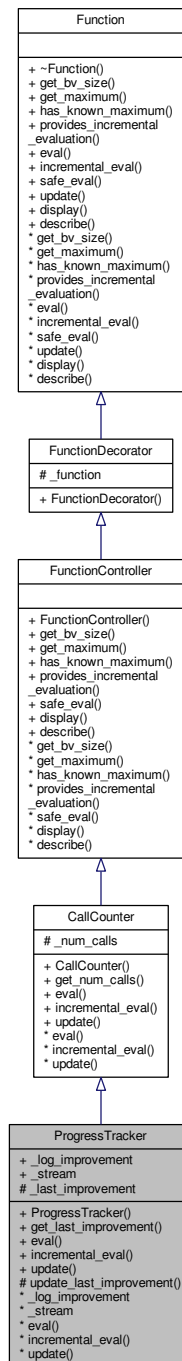
- lib/hnco/functions/decorators/prior-noise.hh
- lib/hnco/functions/decorators/prior-noise.cc

5.70 ProgressTracker Class Reference

[ProgressTracker](#).

```
#include <hnco/functions/decorators/function-controller.hh>
```

Inheritance diagram for ProgressTracker:



Classes

- struct [Event](#)
- [Event](#).

Public Member Functions

- [ProgressTracker](#) ([Function](#) *function)
Constructor.
- const [Event](#) & [get_last_improvement](#) ()
Get the last improvement.

Evaluation

- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- double [incremental_eval](#) (const [bit_vector_t](#) &x, double value, const [hnco::sparse_bit_vector_t](#) &flipped←_bits)
Incremental evaluation.
- void [update](#) (const [bit_vector_t](#) &x, double value)
Update after a safe evaluation.

Public Attributes

Parameters

- bool [_log_improvement](#) = false
Log improvement.
- std::ostream & [_stream](#) = std::cout
Output stream.

Protected Member Functions

- void [update_last_improvement](#) (double value)
Update last improvement.

Protected Attributes

- [Event](#) [_last_improvement](#)
Last improvement.

5.70.1 Detailed Description

[ProgressTracker](#).

A [ProgressTracker](#) is a [CallCounter](#) which records the last event, that is the time and value of the last improvement.

Definition at line 212 of file function-controller.hh.

5.70.2 Member Function Documentation

5.70.2.1 [eval\(\)](#)

```
double eval (
    const bit\_vector\_t & x ) [virtual]
```

Evaluate a bit vector.

Exceptions

<i>MaximumReached</i>	
<i>TargetReached</i>	

Reimplemented from [CallCounter](#).

Definition at line 153 of file function-controller.cc.

5.70.2.2 `get_last_improvement()`

```
const Event& get_last_improvement ( ) [inline]
```

Get the last improvement.

Warning

If `_last_improvement.time` is zero then `_function` has never been called. The [Event](#) returned by `get_last_improvement` has therefore no meaning.

Definition at line 276 of file function-controller.hh.

5.70.2.3 `incremental_eval()`

```
double incremental_eval (
    const bit_vector_t & x,
    double value,
    const hnco::sparse_bit_vector_t & flipped_bits ) [virtual]
```

Incremental evaluation.

Exceptions

<i>MaximumReached</i>	
<i>TargetReached</i>	

Reimplemented from [CallCounter](#).

Definition at line 172 of file function-controller.cc.

5.70.2.4 `update()`

```
void update (
    const bit_vector_t & x,
    double value ) [virtual]
```

Update after a safe evaluation.

Exceptions

<i>MaximumReached</i>	
<i>TargetReached</i>	

Reimplemented from [CallCounter](#).

Definition at line 191 of file function-controller.cc.

The documentation for this class was generated from the following files:

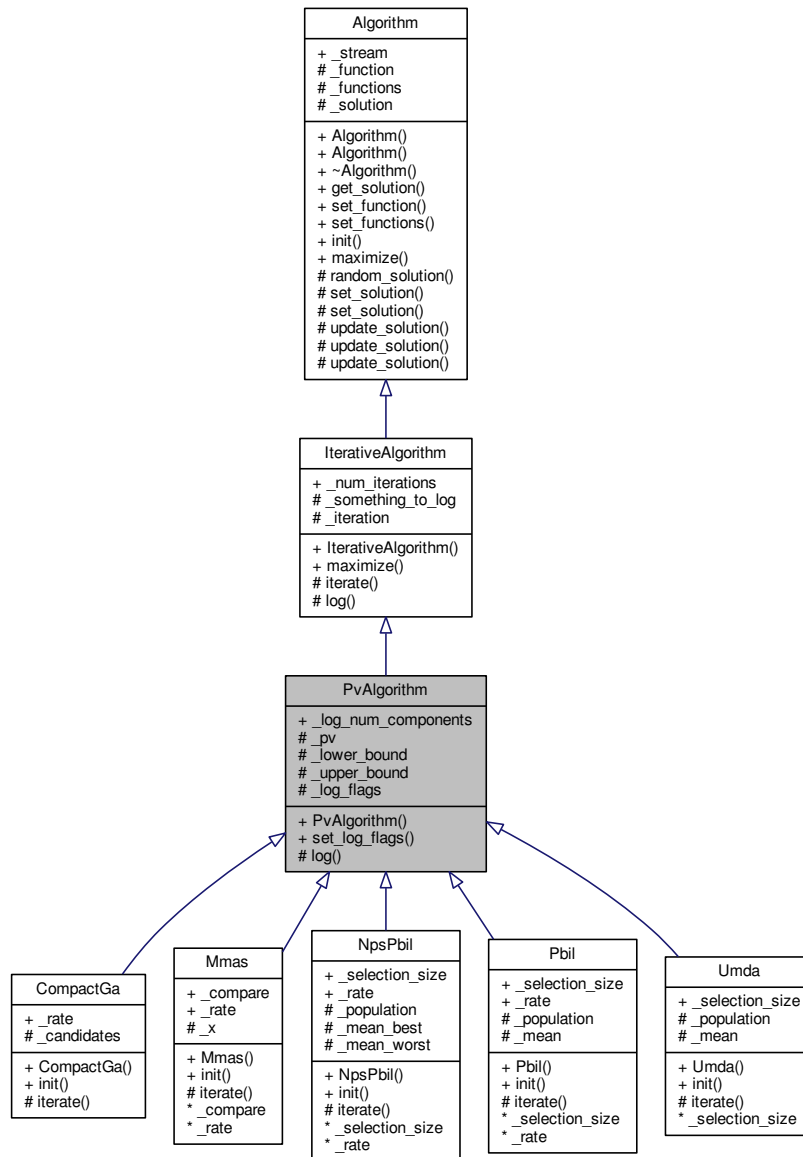
- lib/hnco/functions/decorators/function-controller.hh
- lib/hnco/functions/decorators/function-controller.cc

5.71 PvAlgorithm Class Reference

Probability vector algorithm.

```
#include <hnco/algorithms/pv/pv-algorithm.hh>
```


Inheritance diagram for PvAlgorithm:



Public Types

- enum { `LOG_PV`, `LOG_ENTROPY`, `LAST_LOG` }
- typedef std::bitset< LAST_LOG > `log_flags_t`

Public Member Functions

- `PvAlgorithm` (int n)
Constructor.
- void `set_log_flags` (const `log_flags_t` &lf)
Set log flags.

Public Attributes

- `int _log_num_components = 5`
Number of probability vector components to log.

Protected Member Functions

- `void log ()`
Log.

Protected Attributes

- `pv_t _pv`
Probability vector.
- `double _lower_bound`
Lower bound of probability.
- `double _upper_bound`
Upper bound of probability.
- `log_flags_t _log_flags`
Log flags.

5.71.1 Detailed Description

Probability vector algorithm.

Definition at line 34 of file pv-algorithm.hh.

5.71.2 Member Enumeration Documentation

5.71.2.1 anonymous enum

anonymous enum

Enumerator

LOG_PV	Log probability vector.
LOG_ENTROPY	Log entropy.

Definition at line 39 of file pv-algorithm.hh.

The documentation for this class was generated from the following files:

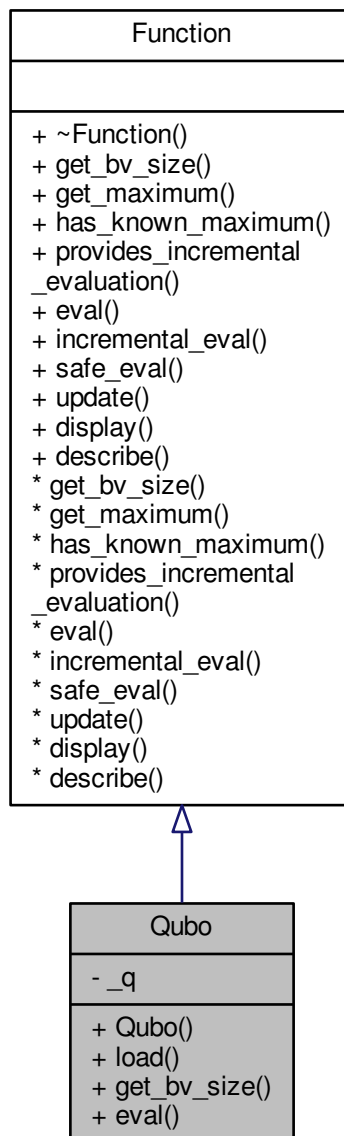
- `lib/hnco/algorithms/pv/pv-algorithm.hh`
- `lib/hnco/algorithms/pv/pv-algorithm.cc`

5.72 Qubo Class Reference

Quadratic unconstrained binary optimization.

```
#include <hnco/functions/qubo.hh>
```

Inheritance diagram for Qubo:



Public Member Functions

- [Qubo \(\)](#)
Constructor.

- void `load` (std::istream &stream)
Load an instance.
- size_t `get_bv_size` ()
Get bit vector size.
- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.

Private Attributes

- std::vector< std::vector< double > > `_q`
Matrix.

5.72.1 Detailed Description

Quadratic unconstrained binary optimization.

Its expression is of the form $f(x) = \sum_i Q_{ii}x_i + \sum_{i < j} Q_{ij}x_ix_{ij} = x^T Qx$, where Q is an n x n upper-triangular matrix.

`Qubo` is the problem addressed by qbsolv. Here is its description as given on github:

Qbsolv, a decomposing solver, finds a minimum value of a large quadratic unconstrained binary optimization (Q↔UBO) problem by splitting it into pieces solved either via a D-Wave system or a classical tabu solver.

There are some differences between `WalshExpansion2` and `Qubo`:

- `WalshExpansion2` maps 0/1 variables into -1/1 variables whereas `Qubo` directly deals with binary variables.
- Hence, there is a separate linear part in `WalshExpansion2` whereas the linear part in `Qubo` stems from the diagonal elements of the given matrix.

qbsolv aims at minimizing quadratic functions whereas hncs algorithms aim at maximizing them. Hence `Qubo::load` negates all elements so that maximizing the resulting function is equivalent to minimizing the original `Qubo`.

References:

Michael Booth, Steven P. Reinhardt, and Aidan Roy. 2017. Partitioning Optimization Problems for Hybrid Classical/Quantum Execution. Technical Report. D-Wave.

<https://github.com/dwavesystems/qbsolv>

<http://people.brunel.ac.uk/~mastjjb/jeb/orlib/bqpinfo.html>

Definition at line 74 of file qubo.hh.

5.72.2 Member Function Documentation

5.72.2.1 `load()`

```
void load (
    std::istream & stream )
```

Load an instance.

Exceptions

Error	
-------	--

Definition at line 36 of file qubo.cc.

5.72.3 Member Data Documentation

5.72.3.1 `_q`

```
std::vector<std::vector<double> > _q [private]
```

Matrix.

$n \times n$ upper triangular matrix.

Definition at line 83 of file qubo.hh.

The documentation for this class was generated from the following files:

- lib/hnco/functions/qubo.hh
- lib/hnco/functions/qubo.cc

5.73 Random Struct Reference

Random numbers.

```
#include <hnco/random.hh>
```

Static Public Member Functions

- static double `uniform` ()
Next uniformly distributed sample.
- static double `normal` ()
Next normally distributed sample.
- static bool `random_bit` ()
Next random bit.

Static Public Attributes

- static std::mt19937 `engine`
Engine.

5.73.1 Detailed Description

Random numbers.

Definition at line 33 of file random.hh.

The documentation for this struct was generated from the following files:

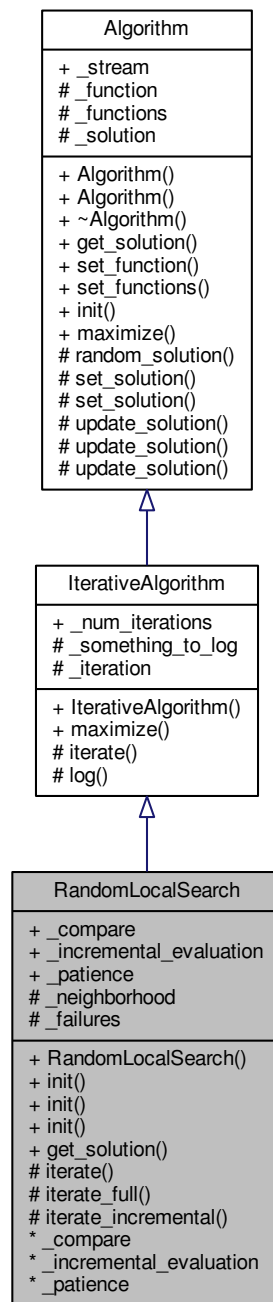
- lib/hnco/random.hh
- lib/hnco/random.cc

5.74 RandomLocalSearch Class Reference

Random local search.

```
#include <hnco/algorithms/ls/random-local-search.hh>
```

Inheritance diagram for RandomLocalSearch:



Public Member Functions

- [RandomLocalSearch](#) (int n, [neighborhood::Neighborhood](#) *neighborhood)
Constructor.
- void [init](#) ()
Random initialization.
- void [init](#) (const [bit_vector_t](#) &x)

Explicit initialization.

- void `init` (const `bit_vector_t` &x, double value)

Explicit initialization.

- const `point_value_t` & `get_solution` ()

Solution.

Public Attributes

Parameters

- `std::function< bool(double, double)> _compare` = `std::greater_equal<double>()`

Binary operator for comparing evaluations.

- bool `_incremental_evaluation` = false

Incremental evaluation.

- int `_patience` = 50

Patience.

Protected Member Functions

- void `iterate` ()

Single iteration.

- void `iterate_full` ()

Single iteration with full evaluation.

- void `iterate_incremental` ()

Single iteration with incremental evaluation.

Protected Attributes

- `neighborhood::Neighborhood` * `_neighborhood`

Neighborhood.

- int `_failures`

Number of failure.

5.74.1 Detailed Description

Random local search.

Definition at line 39 of file random-local-search.hh.

5.74.2 Member Data Documentation

5.74.2.1 _patience

```
int _patience = 50
```

Patience.

Number of consecutive rejected moves before throwing a LocalMaximum exception

If patience ≤ 0 then patience is considered infinite, meaning that the algorithm will never throw any LocalMaximum exception.

Definition at line 97 of file random-local-search.hh.

The documentation for this class was generated from the following files:

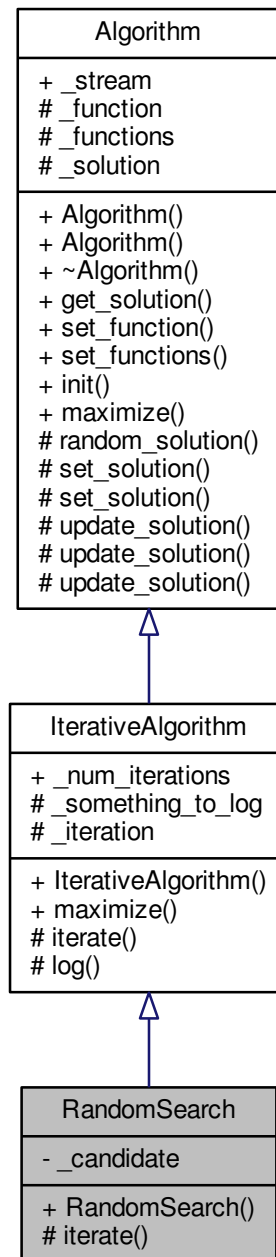
- lib/hnco/algorithms/ls/random-local-search.hh
- lib/hnco/algorithms/ls/random-local-search.cc

5.75 RandomSearch Class Reference

Random search.

```
#include <hnco/algorithms/random-search.hh>
```

Inheritance diagram for RandomSearch:



Public Member Functions

- [RandomSearch](#) (int n)

Constructor.

Protected Member Functions

- void [iterate](#) ()
Single iteration.

Private Attributes

- [bit_vector_t _candidate](#)
Candidate.

Additional Inherited Members

5.75.1 Detailed Description

Random search.

Definition at line 30 of file random-search.hh.

The documentation for this class was generated from the following files:

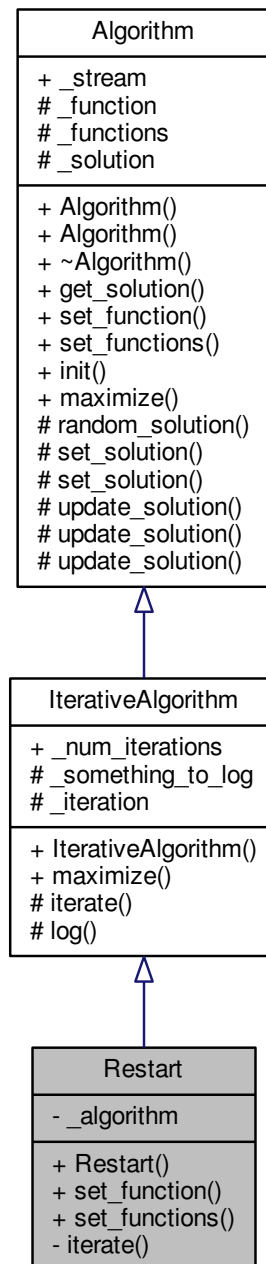
- lib/hnco/algorithms/random-search.hh
- lib/hnco/algorithms/random-search.cc

5.76 Restart Class Reference

[Restart](#).

```
#include <hnco/algorithms/restart.hh>
```

Inheritance diagram for Restart:



Public Member Functions

- [Restart](#) (int n, [Algorithm](#) *algorithm)
Constructor.
- void [set_function](#) (function::Function *function)
Set function.
- void [set_functions](#) (const std::vector< [function::Function](#) *> functions)
Set functions.

Private Member Functions

- void [iterate](#) ()
Optimize.

Private Attributes

- [Algorithm](#) * [_algorithm](#)
Algorithm.

Additional Inherited Members

5.76.1 Detailed Description

[Restart](#).

[Restart](#) an [Algorithm](#) an indefinite number of times. Should be used in conjunction with `OnBudgetFunction` or `StopOnMaximum`.

Definition at line 38 of file `restart.hh`.

The documentation for this class was generated from the following files:

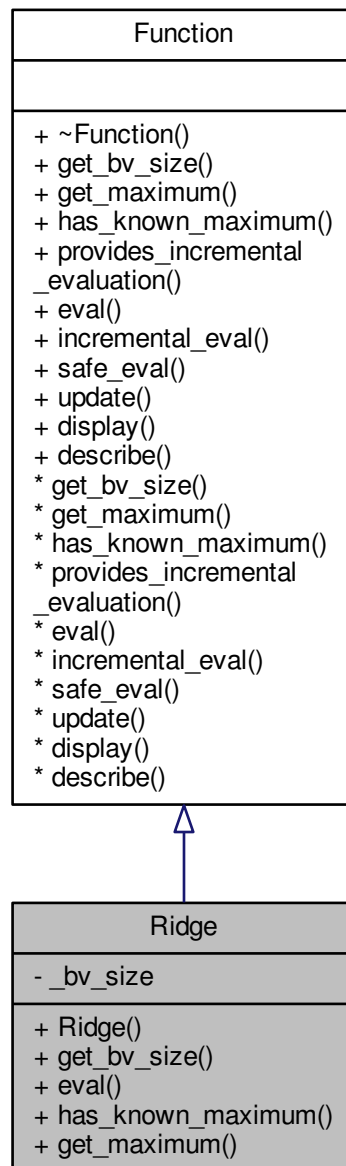
- `lib/hnco/algorithms/restart.hh`
- `lib/hnco/algorithms/restart.cc`

5.77 Ridge Class Reference

[Ridge](#).

```
#include <hnco/functions/theory.hh>
```

Inheritance diagram for Ridge:



Public Member Functions

- [Ridge](#) (int bv_size)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- `bool` [has_known_maximum](#) ()

Check for a known maximum.

- double [get_maximum](#) ()

Get the global maximum.

Private Attributes

- size_t [_bv_size](#)

Bit vector size.

5.77.1 Detailed Description

[Ridge](#).

Reference:

Thomas Jansen. 2013. Analyzing Evolutionary Algorithms. Springer.

Definition at line 203 of file theory.hh.

5.77.2 Member Function Documentation

5.77.2.1 [get_maximum](#)()

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

2 * [_bv_size](#)

Reimplemented from [Function](#).

Definition at line 227 of file theory.hh.

5.77.2.2 [has_known_maximum](#)()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 223 of file theory.hh.

The documentation for this class was generated from the following files:

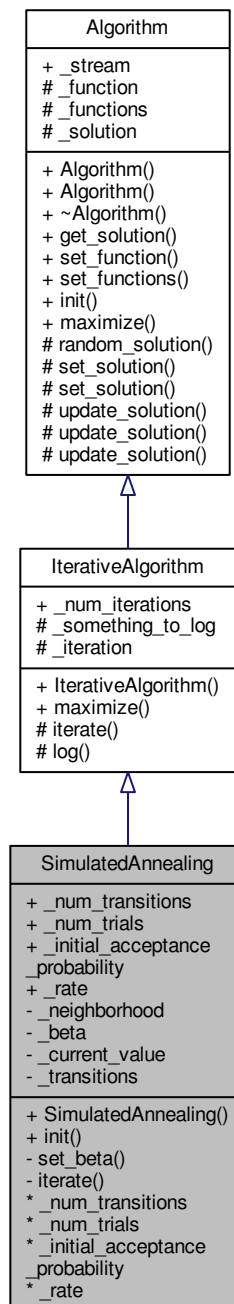
- lib/hnco/functions/theory.hh
- lib/hnco/functions/theory.cc

5.78 SimulatedAnnealing Class Reference

Simulated annealing.

```
#include <hnco/algorithms/ls/simulated-annealing.hh>
```

Inheritance diagram for SimulatedAnnealing:



Public Member Functions

- [SimulatedAnnealing](#) (int n, [neighborhood::Neighborhood](#) *neighborhood)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- int [_num_transitions](#) = 50
Number of accepted transitions before annealing.
- int [_num_trials](#) = 100
Number of trials.
- double [_initial_acceptance_probability](#) = 0.6
Initial acceptance probability.
- double [_rate](#) = 1.2
Increase rate for inverse temperature.

Private Member Functions

- void [set_beta](#) ()
Set beta.
- void [iterate](#) ()
Single iteration.

Private Attributes

- [neighborhood::Neighborhood](#) * [_neighborhood](#)
Neighborhood.
- double [_beta](#)
Inverse temperature.
- double [_current_value](#)
Current value.
- int [_transitions](#)
Number of accepted transitions.

Additional Inherited Members

5.78.1 Detailed Description

Simulated annealing.

Reference:

S. Kirkpatrick, C. D. Gelatt, and M. P. Vecchi. 1983. Optimization by simulated annealing. Science 220, 4598 (May 1983), 671–680.

Definition at line 44 of file simulated-annealing.hh.

5.78.2 Member Function Documentation

5.78.2.1 set_beta()

```
void set_beta ( ) [private]
```

Set beta.

Requires $(2 * \text{num_trials})$ evaluations. This should be taken into account when using OnBudgetFunction.

Definition at line 34 of file simulated-annealing.cc.

The documentation for this class was generated from the following files:

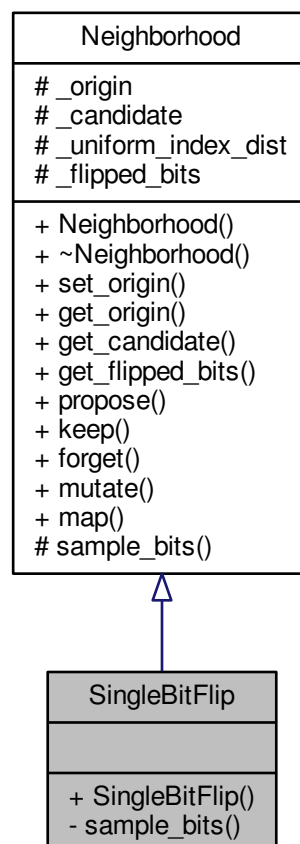
- lib/hnco/algorithms/ls/simulated-annealing.hh
- lib/hnco/algorithms/ls/simulated-annealing.cc

5.79 SingleBitFlip Class Reference

One bit neighborhood.

```
#include <hnco/neighborhoods/neighborhood.hh>
```

Inheritance diagram for SingleBitFlip:



Public Member Functions

- [SingleBitFlip](#) (int n)

Constructor.

Private Member Functions

- void [sample_bits](#) ()

Sample bits.

Additional Inherited Members

5.79.1 Detailed Description

One bit neighborhood.

Definition at line 160 of file neighborhood.hh.

The documentation for this class was generated from the following file:

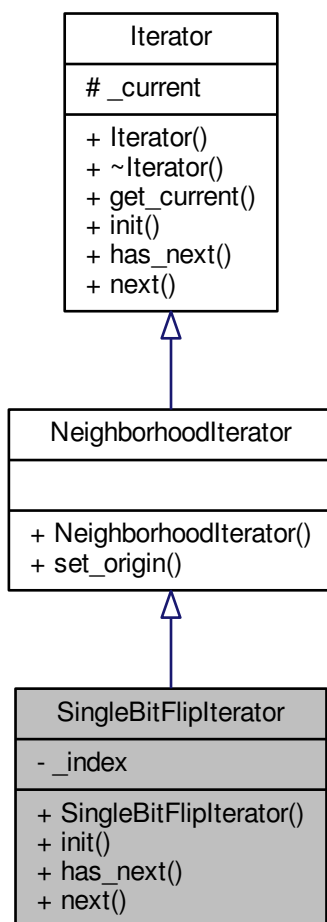
- lib/hnco/neighborhoods/neighborhood.hh

5.80 SingleBitFlipIterator Class Reference

Single bit flip neighborhood iterator.

```
#include <hnco/neighborhoods/neighborhood-iterator.hh>
```

Inheritance diagram for SingleBitFlipIterator:



Public Member Functions

- [SingleBitFlipIterator](#) (int n)
Constructor.
- void [init](#) ()
Initialization.
- bool [has_next](#) ()
Has next bit vector.
- void [next](#) ()
Next bit vector.

Private Attributes

- `size_t` [_index](#)
Index of the last flipped bit.

Additional Inherited Members

5.80.1 Detailed Description

Single bit flip neighborhood iterator.

Definition at line 58 of file neighborhood-iterator.hh.

5.80.2 Constructor & Destructor Documentation

5.80.2.1 SingleBitFlipIterator()

```
SingleBitFlipIterator (
    int n ) [inline]
```

Constructor.

Parameters

n	Size of bit vectors
-----	---------------------

Definition at line 70 of file neighborhood-iterator.hh.

The documentation for this class was generated from the following files:

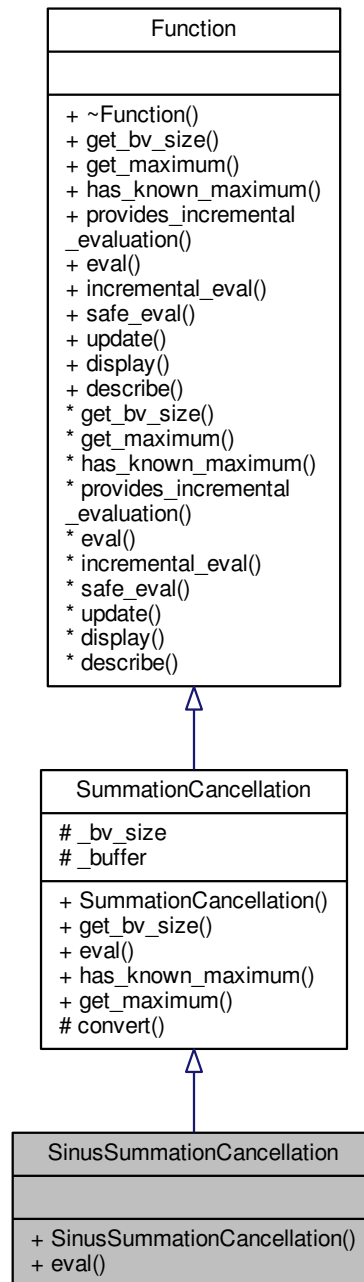
- lib/hnco/neighborhoods/neighborhood-iterator.hh
- lib/hnco/neighborhoods/neighborhood-iterator.cc

5.81 SinusSummationCancellation Class Reference

Summation cancellation with sinus.

```
#include <hnco/functions/cancellation.hh>
```

Inheritance diagram for SinusSummationCancellation:



Public Member Functions

- [SinusSummationCancellation](#) (int n)
Constructor.
- double [eval](#) (const [bit_vector_t](#) &x)
Evaluate a bit vector.

Additional Inherited Members

5.81.1 Detailed Description

Summation cancellation with sinus.

Reference:

M. Sebag and M. Schoenauer. 1997. A society of hill-climbers. In Proc. IEEE Int. Conf. on Evolutionary Computation. Indianapolis, 319–324.

Definition at line 103 of file cancellation.hh.

The documentation for this class was generated from the following files:

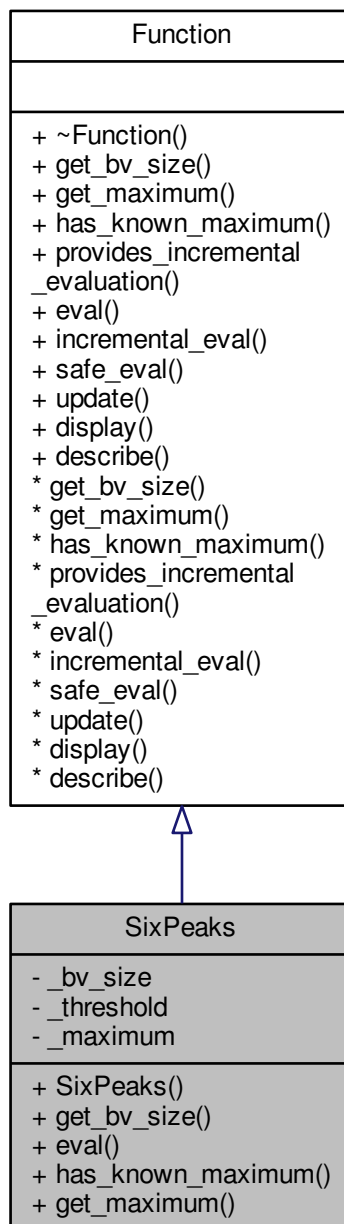
- lib/hnco/functions/cancellation.hh
- lib/hnco/functions/cancellation.cc

5.82 SixPeaks Class Reference

Six Peaks.

```
#include <hnco/functions/four-peaks.hh>
```

Inheritance diagram for SixPeaks:



Public Member Functions

- [SixPeaks](#) (int bv_size, int threshold)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &)

Evaluate a bit vector.

- bool `has_known_maximum()`

Check for a known maximum.

- double `get_maximum()`

Get the global maximum.

Private Attributes

- size_t `_bv_size`

Bit vector size.

- int `_threshold`

Threshold.

- int `_maximum`

Maximum.

5.82.1 Detailed Description

Six Peaks.

It is defined by

$$f(x) = \max\{\text{head}(x, 0) + \text{tail}(x, 1) + \text{head}(x, 1) + \text{tail}(x, 0)\} + R(x)$$

where:

- $\text{head}(x, 0)$ is the length of the longest prefix of x made of zeros;
- $\text{head}(x, 1)$ is the length of the longest prefix of x made of ones;
- $\text{tail}(x, 0)$ is the length of the longest suffix of x made of zeros;
- $\text{tail}(x, 1)$ is the length of the longest suffix of x made of ones;
- $R(x)$ is the reward;
- $R(x) = n$ if $(\text{head}(x, 0) > t \text{ and } \text{tail}(x, 1) > t) \text{ or } (\text{head}(x, 1) > t \text{ and } \text{tail}(x, 0) > t)$;
- $R(x) = 0$ otherwise;
- the threshold t is a parameter of the function.

This function has six maxima, of which exactly four are global ones.

For example, if $n = 6$ and $t = 1$:

- $f(111111) = 6$ (local maximum)
- $f(111110) = 5$
- $f(111100) = 10$ (global maximum)

Reference:

J. S. De Bonet, C. L. Isbell, and P. Viola. 1996. MIMIC: finding optima by estimating probability densities. In *Advances in Neural Information Processing Systems*. Vol. 9. MIT Press, Denver.

Definition at line 128 of file `four-peaks.hh`.

5.82.2 Member Function Documentation

5.82.2.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

$2 * _bv_size - _threshold - 1$

Reimplemented from [Function](#).

Definition at line 159 of file four-peaks.hh.

5.82.2.2 `has_known_maximum()`

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 155 of file four-peaks.hh.

The documentation for this class was generated from the following files:

- lib/hnco/functions/four-peaks.hh
- lib/hnco/functions/four-peaks.cc

5.83 SpinHerding Class Reference

Herding with spin variables.

```
#include <hnco/algorithms/hea/herding-spin.hh>
```

Public Types

- enum {
 [SAMPLE_GREEDY](#), [SAMPLE_RLS](#), [SAMPLE_DLS](#), [SAMPLE_NN](#),
 [LAST_SAMPLE](#) }

Public Member Functions

- [SpinHerdng](#) (int n)
Constructor.
- void [init](#) ()
Initialization.
- double [error](#) (const [SpinMoment](#) &target)
Compute the error.
- double [delta](#) (const [SpinMoment](#) &target)
Compute the norm of the moment increment.
- void [sample](#) (const [SpinMoment](#) &target, [bit_vector_t](#) &x)
Sample a bit vector.

Public Attributes

Parameters

- bool [_randomize_bit_order](#) = false
Randomize bit order.
- int [_sampling_method](#) = [SAMPLE_GREEDY](#)
Sampling method.
- int [_num_seq_updates](#)
Number of sequential updates per sample.
- int [_num_par_updates](#) = 1
Number of parallel updates per sample.
- double [_weight](#) = 1
Weight of second order moments.

Protected Member Functions

- void [compute_delta](#) (const [SpinMoment](#) &target)
Compute delta.
- void [sample_greedy](#) ([bit_vector_t](#) &x)
Sample by means of a greedy algorithm.
- double [q_derivative](#) (const [bit_vector_t](#) &x, size_t i)
Derivative of q.
- double [q_variation](#) (const [bit_vector_t](#) &x, size_t i)
Variation of q.
- void [sample_rls](#) ([bit_vector_t](#) &x)
Sample by means of random local search.
- void [sample_dls](#) ([bit_vector_t](#) &x)
Sample by means of deterministic local search.
- void [sample_nn](#) ([bit_vector_t](#) &x)
Sample by means of a neural network.
- void [update_counters](#) (const [bit_vector_t](#) &x)
Update counters.

Protected Attributes

- [SpinMoment_delta](#)
Delta moment.
- [SpinMoment_count](#)
Counter moment.
- [bit_vector_t_state](#)
State.
- [permutation_t_permutation](#)
Permutation.
- `std::uniform_int_distribution< int > _choose_bit`
Choose bit.
- `int _time`
Time.

5.83.1 Detailed Description

Herding with spin variables.

By spin variables, we mean variables taking values 1 or -1, instead of 0 or 1 in the case of binary variables.

Definition at line 37 of file herding-spin.hh.

5.83.2 Member Enumeration Documentation

5.83.2.1 anonymous enum

`anonymous enum`

Enumerator

<code>SAMPLE_GREEDY</code>	Greedy algorithm.
<code>SAMPLE_RLS</code>	Random local search.
<code>SAMPLE_DLS</code>	Deterministic local search.
<code>SAMPLE_NN</code>	Neural network.

Definition at line 90 of file herding-spin.hh.

5.83.3 Member Function Documentation

5.83.3.1 q_variation()

```
double q_variation (
    const bit_vector_t & x,
    size_t i ) [protected]
```

Variation of q.

Up to a positive multiplicative constant. Only the sign of the variation matters to local search.

Definition at line 155 of file herding-spin.cc.

The documentation for this class was generated from the following files:

- lib/hnco/algorithms/hea/herding-spin.hh
- lib/hnco/algorithms/hea/herding-spin.cc

5.84 SpinMoment Struct Reference

Moment for spin variables.

```
#include <hnco/algorithms/hea/moment-spin.hh>
```

Public Member Functions

- [SpinMoment](#) (int n)
Constructor.
- void [uniform](#) ()
Set the moment to that of the uniform distribution.
- void [init](#) ()
Initialize accumulators.
- void [add](#) (const [bit_vector_t](#) &x)
Update accumulators.
- void [average](#) (int count)
Compute average.
- void [update](#) (const [SpinMoment](#) &p, double rate)
Update moment.
- void [bound](#) (double margin)
Bound moment.
- double [distance](#) (const [SpinMoment](#) &p) const
Distance.
- double [norm_2](#) () const
Compute the norm 2.
- double [diameter](#) () const
Compute the diameter.
- size_t [size](#) () const
Size.

Public Attributes

- `std::vector< double > _first`
First moment.
- `std::vector< std::vector< double > > _second`
Second moment.
- `double _weight = 1`
Weight of second order moments.

5.84.1 Detailed Description

Moment for spin variables.

Definition at line 35 of file moment-spin.hh.

The documentation for this struct was generated from the following files:

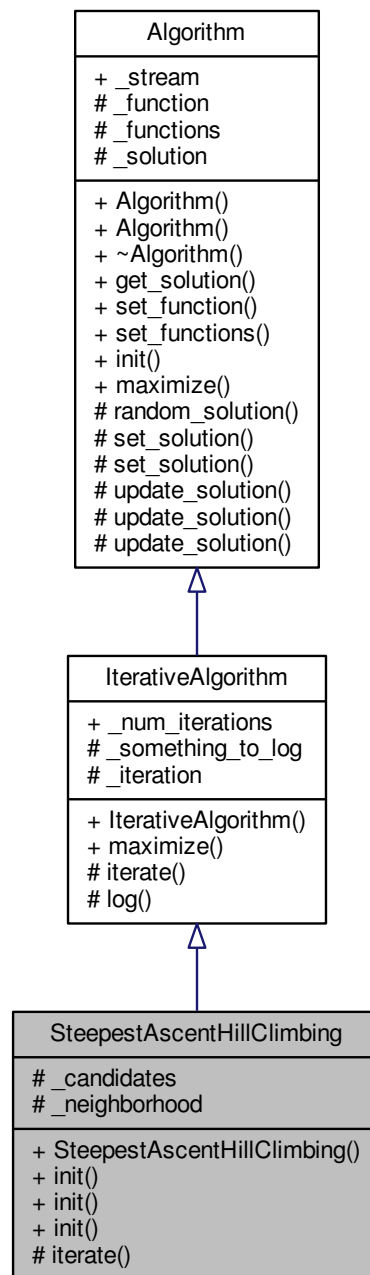
- `lib/hnco/algorithms/hea/moment-spin.hh`
- `lib/hnco/algorithms/hea/moment-spin.cc`

5.85 SteepestAscentHillClimbing Class Reference

Steepest ascent hill climbing.

```
#include <hnco/algorithms/ls/steepest-ascent-hill-climbing.hh>
```

Inheritance diagram for SteepestAscentHillClimbing:



Public Member Functions

- [SteepestAscentHillClimbing](#) (int n, [neighborhood::NeighborhoodIterator](#) *neighborhood)
Constructor.
- void [init](#) ()
Random initialization.
- void [init](#) (const [bit_vector_t](#) &x)

Explicit initialization.

- void `init` (const `bit_vector_t` &x, double value)

Explicit initialization.

Protected Member Functions

- void `iterate` ()

Single iteration.

Protected Attributes

- `std::vector< bit_vector_t > _candidates`

Potential candidate.

- `neighborhood::NeighborhoodIterator * _neighborhood`

Neighborhood.

Additional Inherited Members

5.85.1 Detailed Description

Steepest ascent hill climbing.

Definition at line 39 of file `steepest-ascent-hill-climbing.hh`.

The documentation for this class was generated from the following files:

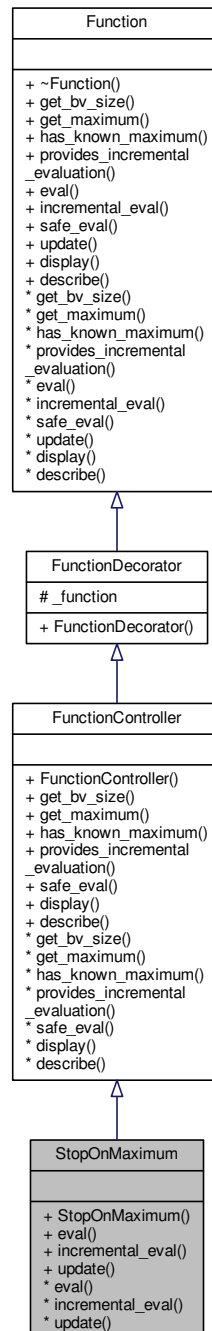
- `lib/hnco/algorithms/ls/steepest-ascent-hill-climbing.hh`
- `lib/hnco/algorithms/ls/steepest-ascent-hill-climbing.cc`

5.86 StopOnMaximum Class Reference

Stop on maximum.

```
#include <hnco/functions/decorators/function-controller.hh>
```


Inheritance diagram for StopOnMaximum:



Public Member Functions

- [StopOnMaximum](#) ([Function](#) *function)
Constructor.

Evaluation

- double `eval` (const `bit_vector_t` &)
Evaluate a bit vector.
- double `incremental_eval` (const `bit_vector_t` &x, double value, const `hnco::sparse_bit_vector_t` &flipped↔
_bits)
Incremental evaluation.
- void `update` (const `bit_vector_t` &x, double value)
Update after a safe evaluation.

Additional Inherited Members

5.86.1 Detailed Description

Stop on maximum.

The `eval()` member function throws a `MaximumReached` exception when its argument maximizes the decorated function.

Definition at line 98 of file `function-controller.hh`.

5.86.2 Constructor & Destructor Documentation

5.86.2.1 StopOnMaximum()

```
StopOnMaximum (
    Function * function ) [inline]
```

Constructor.

Parameters

<code>function</code>	Decorated function
-----------------------	--------------------

Precondition

`function->has_known_maximum()`

Definition at line 106 of file `function-controller.hh`.

5.86.3 Member Function Documentation

5.86.3.1 eval()

```
double eval (
    const bit_vector_t & x ) [virtual]
```

Evaluate a bit vector.

Exceptions

<i>MaximumReached</i>	
-----------------------	--

Implements [Function](#).

Definition at line 31 of file function-controller.cc.

5.86.3.2 incremental_eval()

```
double incremental_eval (
    const bit\_vector\_t & x,
    double value,
    const hnco::sparse\_bit\_vector\_t & flipped_bits ) [virtual]
```

Incremental evaluation.

Exceptions

<i>MaximumReached</i>	
-----------------------	--

Reimplemented from [Function](#).

Definition at line 43 of file function-controller.cc.

5.86.3.3 update()

```
void update (
    const bit\_vector\_t & x,
    double value ) [virtual]
```

Update after a safe evaluation.

Exceptions

<i>MaximumReached</i>	
-----------------------	--

Reimplemented from [Function](#).

Definition at line 55 of file function-controller.cc.

The documentation for this class was generated from the following files:

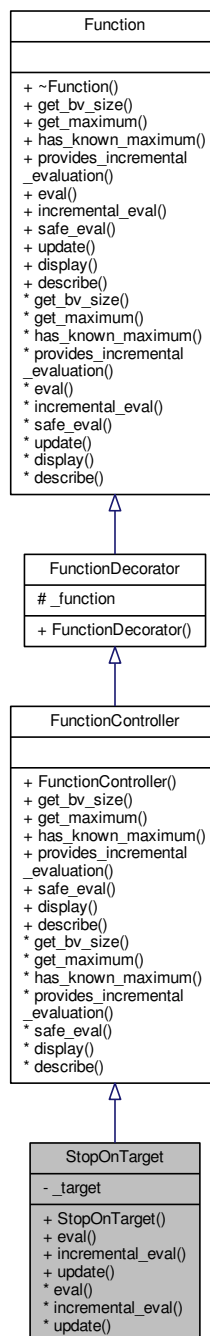
- lib/hnco/functions/decorators/function-controller.hh
- lib/hnco/functions/decorators/function-controller.cc

5.87 StopOnTarget Class Reference

Stop on target.

```
#include <hnco/functions/decorators/function-controller.hh>
```

Inheritance diagram for StopOnTarget:



Public Member Functions

- [StopOnTarget](#) ([Function](#) *function, double target)
Constructor.

Evaluation

- double [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.
- double [incremental_eval](#) (const [bit_vector_t](#) &x, double value, const [hnco::sparse_bit_vector_t](#) &flipped, [_bits](#))
Incremental evaluation.
- void [update](#) (const [bit_vector_t](#) &x, double value)
Update after a safe evaluation.

Private Attributes

- double [_target](#)
Target.

Additional Inherited Members

5.87.1 Detailed Description

Stop on target.

Definition at line 134 of file function-controller.hh.

5.87.2 Constructor & Destructor Documentation

5.87.2.1 StopOnTarget()

```
StopOnTarget (
    Function * function,
    double target ) [inline]
```

Constructor.

Parameters

<i>function</i>	Decorated function
-----------------	--------------------

Definition at line 144 of file function-controller.hh.

5.87.3 Member Function Documentation

5.87.3.1 eval()

```
double eval (
    const bit\_vector\_t & x ) [virtual]
```

Evaluate a bit vector.

Exceptions

<i>TargetReached</i>	
----------------------	--

Implements [Function](#).

Definition at line 66 of file function-controller.cc.

5.87.3.2 incremental_eval()

```
double incremental_eval (
    const bit\_vector\_t & x,
    double value,
    const hnco::sparse\_bit\_vector\_t & flipped_bits ) [virtual]
```

Incremental evaluation.

Exceptions

<i>TargetReached</i>	
----------------------	--

Reimplemented from [Function](#).

Definition at line 76 of file function-controller.cc.

5.87.3.3 update()

```
void update (
    const bit\_vector\_t & x,
    double value ) [virtual]
```

Update after a safe evaluation.

Exceptions

<i>TargetReached</i>	
----------------------	--

Reimplemented from [Function](#).

Definition at line 86 of file function-controller.cc.

The documentation for this class was generated from the following files:

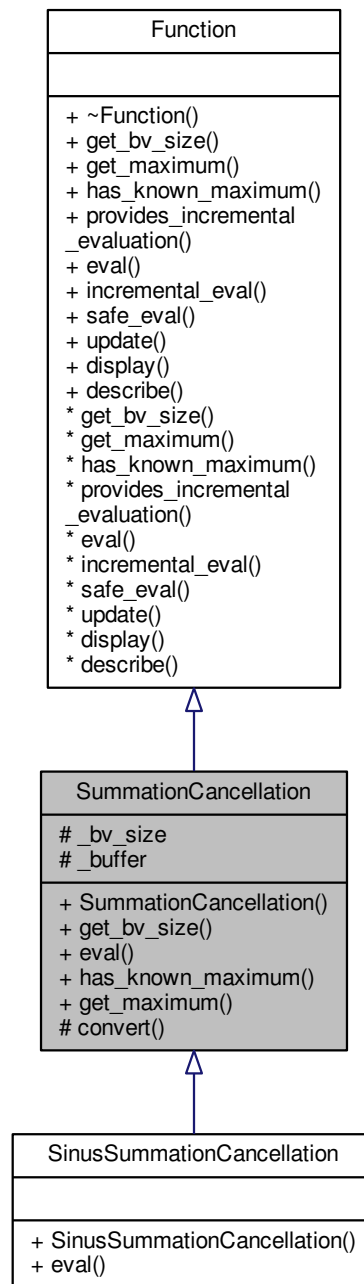
- lib/hnco/functions/decorators/function-controller.hh
- lib/hnco/functions/decorators/function-controller.cc

5.88 SummationCancellation Class Reference

Summation cancellation.

```
#include <hnco/functions/cancellation.hh>
```

Inheritance diagram for SummationCancellation:



Public Member Functions

- [SummationCancellation](#) (int n)
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const [bit_vector_t](#) &x)

Evaluate a bit vector.

- bool `has_known_maximum` ()

Check for a known maximum.

- double `get_maximum` ()

Get the global maximum.

Protected Member Functions

- void `convert` (const `bit_vector_t` &x)

Convert a bit vector into a real vector.

Protected Attributes

- size_t `_bv_size`

Bit vector size.

- std::vector< double > `_buffer`

Buffer.

5.88.1 Detailed Description

Summation cancellation.

Encoding of a signed integer:

- bit 0: sign
- bits 1 to 8: two's complement representation

Reference:

S. Baluja and S. Davies. 1997. Using optimal dependency-trees for combinatorial optimization: learning the structure of the search space. Technical Report CMU- CS-97-107. Carnegie-Mellon University.

Definition at line 47 of file `cancellation.hh`.

5.88.2 Constructor & Destructor Documentation

5.88.2.1 SummationCancellation()

```
SummationCancellation (
    int n ) [inline]
```

Constructor.

The bit vector size `n` must be a multiple of 9. The size of `_buffer` is then `n / 9`.

Parameters

n	Size of the bit vector
-----	------------------------

Definition at line 70 of file cancellation.hh.

5.88.3 Member Function Documentation

5.88.3.1 has_known_maximum()

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

true

Reimplemented from [Function](#).

Definition at line 86 of file cancellation.hh.

The documentation for this class was generated from the following files:

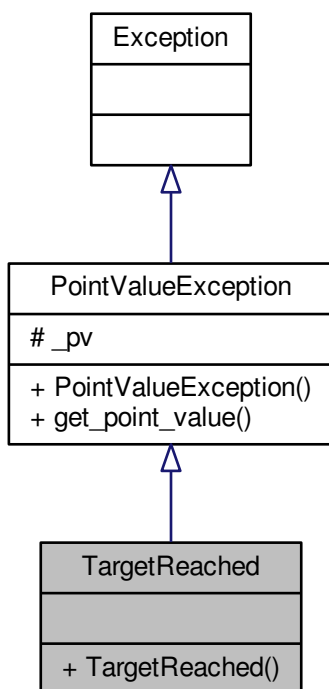
- lib/hnco/functions/cancellation.hh
- lib/hnco/functions/cancellation.cc

5.89 TargetReached Class Reference

target reached

```
#include <hnco/exception.hh>
```

Inheritance diagram for TargetReached:



Public Member Functions

- [TargetReached](#) (const [point_value_t](#) &pv)
Constructor.

Additional Inherited Members

5.89.1 Detailed Description

target reached

Definition at line 61 of file `exception.hh`.

The documentation for this class was generated from the following file:

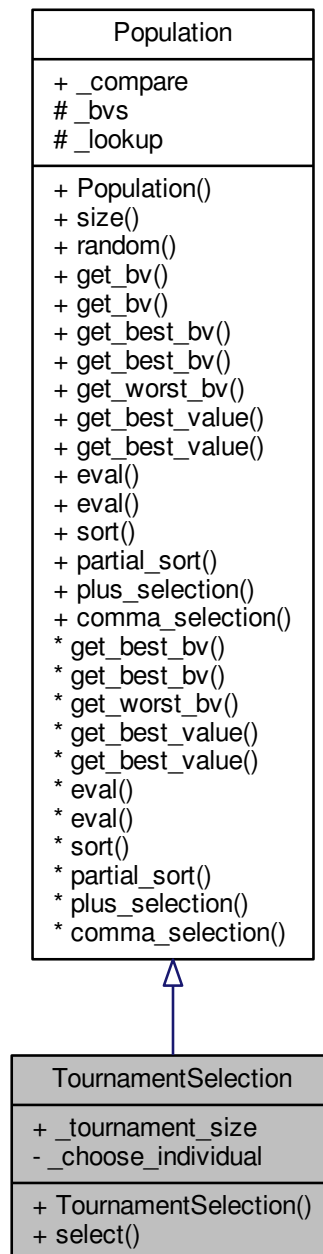
- `lib/hnco/exception.hh`

5.90 TournamentSelection Class Reference

[Population](#) with tournament selection.

```
#include <hnco/algorithms/ea/tournament-selection.hh>
```

Inheritance diagram for TournamentSelection:



Public Member Functions

- [TournamentSelection](#) (int population_size, int n)
Constructor.
- const [bit_vector_t](#) & [select](#) ()
Selection.

Public Attributes

- int [_tournament_size](#) = 10
Tournament size.

Private Attributes

- std::uniform_int_distribution< int > [_choose_individual](#)
Random index.

Additional Inherited Members

5.90.1 Detailed Description

[Population](#) with tournament selection.

Definition at line 34 of file tournament-selection.hh.

5.90.2 Member Function Documentation

5.90.2.1 [select\(\)](#)

```
const bit\_vector\_t & select ( )
```

Selection.

The selection only requires that the population be evaluated, not necessarily sorted.

Precondition

The population must be evaluated.

Definition at line 33 of file tournament-selection.cc.

The documentation for this class was generated from the following files:

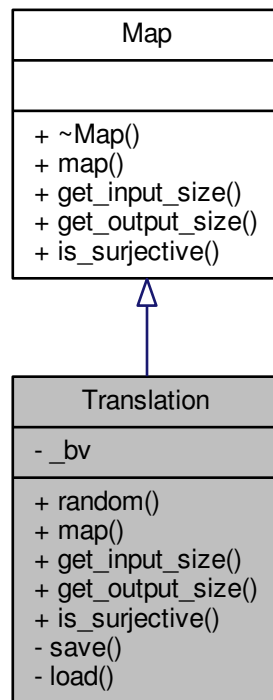
- lib/hnco/algorithms/ea/tournament-selection.hh
- lib/hnco/algorithms/ea/tournament-selection.cc

5.91 Translation Class Reference

[Translation](#).

```
#include <hnco/map.hh>
```

Inheritance diagram for Translation:



Public Member Functions

- void [random](#) (int n)
Random instance.
- void [map](#) (const [bit_vector_t](#) &input, [bit_vector_t](#) &output)
Map.
- size_t [get_input_size](#) ()
Get input size.
- size_t [get_output_size](#) ()
Get output size.
- bool [is_surjective](#) ()
Check for surjective map.

Private Member Functions

- template<class Archive >
void [save](#) (Archive &ar, const unsigned int version) const
Save.
- template<class Archive >
void [load](#) (Archive &ar, const unsigned int version)
Load.

Private Attributes

- [bit_vector_t _bv](#)
Translation vector.

Friends

- class **boost::serialization::access**

5.91.1 Detailed Description

[Translation](#).

A translation is an affine map f from Z_2^n to itself defined by $f(x) = x + b$, where b is an n -dimensional bit vector.

Definition at line 70 of file map.hh.

5.91.2 Member Function Documentation

5.91.2.1 is_surjective()

```
bool is_surjective ( ) [inline], [virtual]
```

Check for surjective map.

Returns

true

Reimplemented from [Map](#).

Definition at line 121 of file map.hh.

The documentation for this class was generated from the following files:

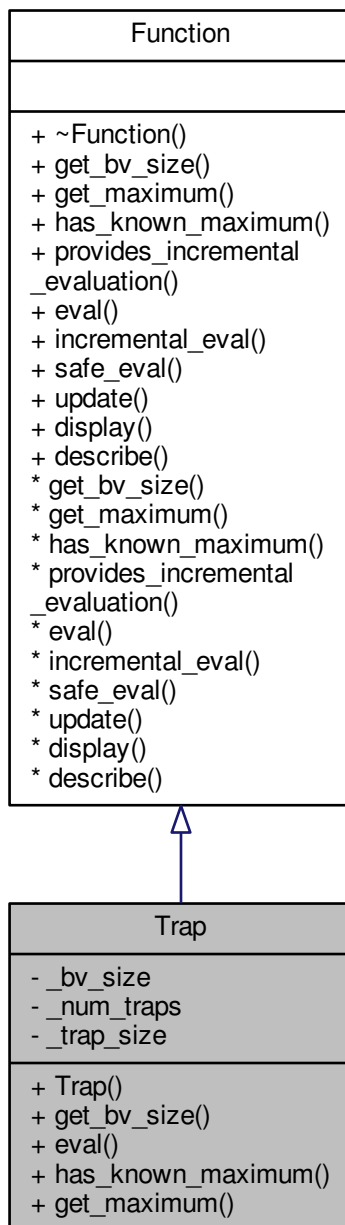
- lib/hnco/map.hh
- lib/hnco/map.cc

5.92 Trap Class Reference

[Trap](#).

```
#include <hnco/functions/trap.hh>
```

Inheritance diagram for Trap:



Public Member Functions

- [Trap](#) (int bv_size, int num_traps)

Constructor.

- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `double` [eval](#) (const `bit_vector_t` &)
Evaluate a bit vector.
- `bool` [has_known_maximum](#) ()
Check for a known maximum.
- `double` [get_maximum](#) ()
Get the global maximum.

Private Attributes

- `size_t` [_bv_size](#)
Bit vector size.
- `int` [_num_traps](#)
Number of traps.
- `int` [_trap_size](#)
Trap size.

5.92.1 Detailed Description

[Trap](#).

Reference:

Kalyanmoy Deb and David E. Goldberg. 1993. Analyzing Deception in Trap Functions. In Foundations of Genetic Algorithms 2, L. Darrell Whitley (Ed.). Morgan Kaufmann, San Mateo, CA, 93–108.

Definition at line 43 of file trap.hh.

5.92.2 Constructor & Destructor Documentation

5.92.2.1 Trap()

```
Trap (
    int bv_size,
    int num_traps ) [inline]
```

Constructor.

Parameters

<i>bv_size</i>	Bit vector size
<i>num_traps</i>	Number of traps

Warning

`bv_size` must be a multiple of `num_traps`

Definition at line 64 of file `trap.hh`.

5.92.3 Member Function Documentation

5.92.3.1 `get_maximum()`

```
double get_maximum ( ) [inline], [virtual]
```

Get the global maximum.

Returns

`_bv_size`

Reimplemented from [Function](#).

Definition at line 88 of file `trap.hh`.

5.92.3.2 `has_known_maximum()`

```
bool has_known_maximum ( ) [inline], [virtual]
```

Check for a known maximum.

Returns

`true`

Reimplemented from [Function](#).

Definition at line 84 of file `trap.hh`.

The documentation for this class was generated from the following files:

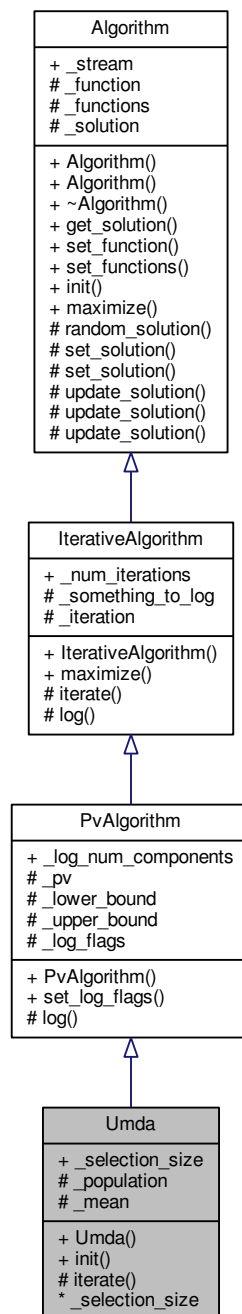
- `lib/hnco/functions/trap.hh`
- `lib/hnco/functions/trap.cc`

5.93 Umda Class Reference

Univariate marginal distribution algorithm.

```
#include <hnco/algorithms/pv/umda.hh>
```

Inheritance diagram for Umda:



Public Member Functions

- [Umda](#) (int n, int population_size)
Constructor.
- void [init](#) ()
Initialization.

Public Attributes

Parameters

- int [_selection_size](#) = 1
Selection size.

Protected Member Functions

- void [iterate](#) ()
Single iteration.

Protected Attributes

- [Population _population](#)
Population.
- [pv_t _mean](#)
Mean of selected bit vectors.

Additional Inherited Members

5.93.1 Detailed Description

Univariate marginal distribution algorithm.

Reference:

H. Mühlenbein. 1997. The equation for response to selection and its use for prediction. *Evolutionary Computation* 5, 3 (1997), 303–346.

Definition at line 40 of file umda.hh.

The documentation for this class was generated from the following files:

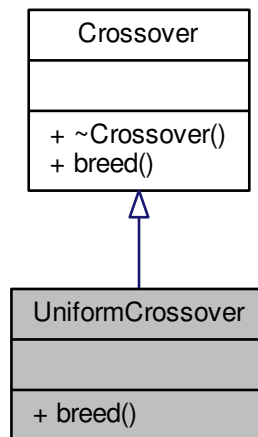
- lib/hnco/algorithms/pv/umda.hh
- lib/hnco/algorithms/pv/umda.cc

5.94 UniformCrossover Class Reference

Uniform crossover.

```
#include <hnco/algorithms/ea/crossover.hh>
```

Inheritance diagram for UniformCrossover:



Public Member Functions

- void `breed` (const `bit_vector_t` &parent1, const `bit_vector_t` &parent2, `bit_vector_t` &offspring)
Breed.

5.94.1 Detailed Description

Uniform crossover.

Definition at line 56 of file `crossover.hh`.

5.94.2 Member Function Documentation

5.94.2.1 `breed()`

```
void breed (
    const bit_vector_t & parent1,
    const bit_vector_t & parent2,
    bit_vector_t & offspring ) [virtual]
```

Breed.

The offspring is the uniform crossover of two parents.

Parameters

<i>parent1</i>	First parent
<i>parent2</i>	Second parent
<i>offspring</i>	Offspring

Implements [Crossover](#).

Definition at line 30 of file crossover.cc.

The documentation for this class was generated from the following files:

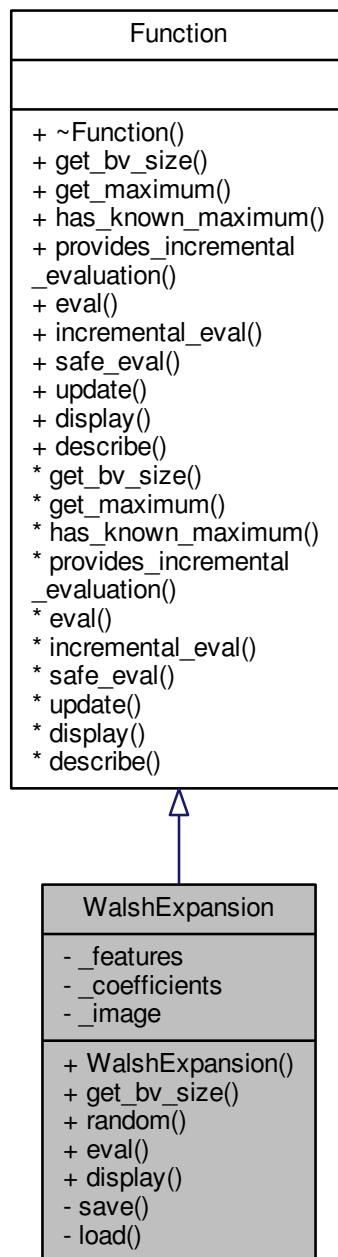
- lib/hnco/algorithms/ea/crossover.hh
- lib/hnco/algorithms/ea/crossover.cc

5.95 WalshExpansion Class Reference

Walsh expansion.

```
#include <hnco/functions/walsh/walsh-expansion.hh>
```

Inheritance diagram for WalshExpansion:



Public Member Functions

- [WalshExpansion](#) ()
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `void` [random](#) (int n, int num_features, double stddev)

- *Random instance.*
- double `eval` (const `bit_vector_t` &)
- *Evaluate a bit vector.*
- void `display` (std::ostream &stream)
- *Display.*

Private Member Functions

- template<class Archive >
void `save` (Archive &ar, const unsigned int version) const
- *Save.*
- template<class Archive >
void `load` (Archive &ar, const unsigned int version)
- *Load.*

Private Attributes

- `hnco::bit_matrix_t _features`
- *Features.*
- std::vector< double > `_coefficients`
- *Coefficients.*
- `bit_vector_t _image`
- *Image of bit vectors under the feature matrix.*

Friends

- class `boost::serialization::access`

5.95.1 Detailed Description

Walsh expansion.

Its expression is of the form

$$f(x) = \sum_u a_u (-1)^{x \cdot u}$$

where the sum is over a subset of $\{0, 1\}^n$ and $x \cdot u = \sum_i x_i u_i$ is mod 2. The real numbers a_u are the coefficients of the expansion and the bit vectors u are its feature vectors.

Definition at line 53 of file walsh-expansion.hh.

5.95.2 Member Function Documentation

5.95.2.1 `random()`

```
void random (
    int n,
    int num_features,
    double stddev )
```

Random instance.

Parameters

<i>n</i>	Size of bit vector
<i>num_features</i>	Number of feature vectors
<i>stddev</i>	Standard deviation of the coefficients

Definition at line 34 of file walsh-expansion.cc.

The documentation for this class was generated from the following files:

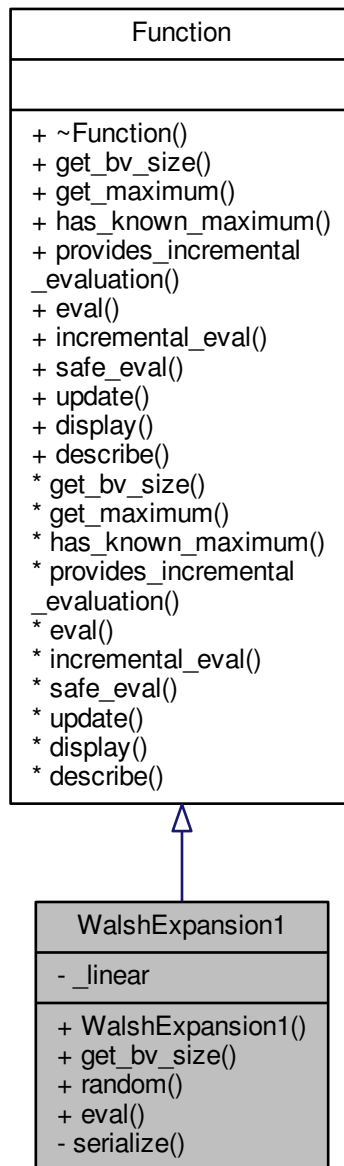
- lib/hnco/functions/walsh/walsh-expansion.hh
- lib/hnco/functions/walsh/walsh-expansion.cc

5.96 WalshExpansion1 Class Reference

Walsh expansion of degree 1.

```
#include <hnco/functions/walsh/walsh-expansion-1.hh>
```

Inheritance diagram for WalshExpansion1:



Public Member Functions

- [WalshExpansion1](#) ()
Constructor.
- `size_t` [get_bv_size](#) ()
Get bit vector size.
- `void` [random](#) (int n, double stddev)
Random instance.
- `double` [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

Private Member Functions

- template<class Archive >
void [serialize](#) (Archive &ar, const unsigned int version)
Serialize.

Private Attributes

- std::vector< double > [_linear](#)
Linear part.

Friends

- class **boost::serialization::access**

5.96.1 Detailed Description

Walsh expansion of degree 1.

Its expression is of the form

$$f(x) = \sum_i a_i (1 - 2x_i)$$

or equivalently

$$f(x) = \sum_i a_i (-1)^{x_i}$$

Definition at line 50 of file walsh-expansion-1.hh.

5.96.2 Member Function Documentation

5.96.2.1 random()

```
void random (
    int n,
    double stddev )
```

Random instance.

Parameters

<i>n</i>	Size of bit vector
<i>stddev</i>	Standard deviation of the coefficients

Definition at line 33 of file walsh-expansion-1.cc.

The documentation for this class was generated from the following files:

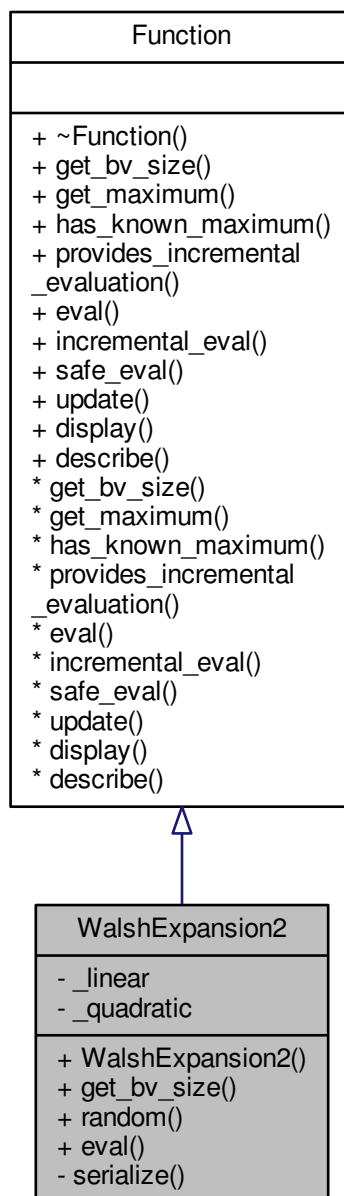
- lib/hnco/functions/walsh/walsh-expansion-1.hh
- lib/hnco/functions/walsh/walsh-expansion-1.cc

5.97 WalshExpansion2 Class Reference

Walsh expansion of degree 2.

```
#include <hnco/functions/walsh/walsh-expansion-2.hh>
```

Inheritance diagram for WalshExpansion2:



Public Member Functions

- [WalshExpansion2](#) ()
Constructor.
- [size_t](#) [get_bv_size](#) ()
Get bit vector size.
- [void](#) [random](#) (int n, double stddev_lin, double stddev_quad)
Random instance.
- [double](#) [eval](#) (const [bit_vector_t](#) &)
Evaluate a bit vector.

Private Member Functions

- `template<class Archive >`
`void` [serialize](#) (Archive &ar, const unsigned int version)
Serialize.

Private Attributes

- `std::vector< double >` [_linear](#)
Linear part.
- `std::vector< std::vector< double > >` [_quadratic](#)
Quadratic part.

Friends

- `class` `boost::serialization::access`

5.97.1 Detailed Description

Walsh expansion of degree 2.

Its expression is of the form

$$f(x) = \sum_i a_i (1 - 2x_i) + \sum_{i < j} a_{ij} (1 - 2x_i)(1 - 2x_j)$$

or equivalently

$$f(x) = \sum_i a_i (-1)^{x_i} + \sum_{i < j} a_{ij} (-1)^{x_i + x_j}$$

where the sum $x_i + x_j$ is mod 2 (xor).

Definition at line 52 of file walsh-expansion-2.hh.

5.97.2 Member Function Documentation

5.97.2.1 random()

```
void random (
    int n,
    double stddev_lin,
    double stddev_quad )
```

Random instance.

Parameters

<i>n</i>	Size of bit vector
<i>stddev_lin</i>	Standard deviation of the coefficients of the linear part
<i>stddev_quad</i>	Standard deviation of the coefficients of the quadratic part

Definition at line 33 of file walsh-expansion-2.cc.

5.97.3 Member Data Documentation

5.97.3.1 `_quadratic`

```
std::vector<std::vector<double> > _quadratic [private]
```

Quadratic part.

Represented as a lower triangular matrix (without its diagonal).

Definition at line 75 of file walsh-expansion-2.hh.

The documentation for this class was generated from the following files:

- lib/hnco/functions/walsh/walsh-expansion-2.hh
- lib/hnco/functions/walsh/walsh-expansion-2.cc

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