

GenAlg

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Introduction

GenAlg is a C library providing structures and functions implementing a Genetic Algorithm.

The genes are memorized as a VecFloat and/or VecShort. The user can defined a range of possible values for each gene. The user can define the size of the pool of entities and the size of the breeding pool. Selection, reproduction and mutation are designed to efficiently explore all the possible gene combination, and avoid local optimum. It is also possible to save and load

the GenAlg.

It uses the PBErr, PBMath and GSet libraries.

1 Definitions

A genetic algorithm has 3 steps. In a pool of entities it discards a given number of entities based on their ranking (given by a mean external to the algorithm). Then it replaces each of the discarded entity by a new one created from two selected entities from the non discarded one. The newly created entity's properties are a mix of these two selected entities, plus a certain amount of random modification. The detail of the implementation in GenAlg of these 3 steps (selection, reproduction and mutation) are given below.

1.1 Selection

The non discarded entities are called 'elite' in GenAlg. The size of the pool of elite is configurable by the user. The selection of two elite entities is simply a random selection in the pool of elites. Selection of the same elite twice is allowed.

1.2 Reproduction

The reproduction step copies the genes of the elite entity into the new entity. Each gene has a probability of 50% to be chosen in one or the other elite.

1.3 Mutation

The mutation occurs as follow. First we calculate the probability of mutation for every gene as follow: $P = \frac{rank}{nbEntity} * (1 - \frac{1}{\sqrt{age+1}})$ where rank is the rank of the discarded entity in the pool of entities, and nbEntity is the number of entities in the pool, and age is the age of the oldest elite entity used during the reproduction step for the entity. A gene affected by a mutation according to this probability is modified as follow. The amplitude of the mutation is equal to $1 - \frac{1}{\sqrt{age+1}}$ where age is the age of the oldest elite entity used during

the reproduction step for the entity. Then the new value of the gene is equals to $gene + range * amp * (rnd + delta)$ where $gene$ is the current value of the gene, $range$ is equal to $max_{gene} - min_{gene}$ (the difference of the maximum allowed value for this gene and its minimum value), amp is the amplitude calculated above, rnd is a random value between -0.5 and 0.5, and $delta$ is the mutation that has been applied to this gene in the corresponding elite entity. Genes' value is kept in bounds by bouncing it on the bounds when necessary ($gene = 2 * bound - gene$)

To counteract inbreeding (the algorithm getting stuck into a local minimum), when the diversity level of the elite pool falls below a threshold, we also reset the adn of all the non entities and all the elite entities (except the best one) having at least one diversity level with another elite entity below the diversity level of the elite pool (set to 0.01 by default). The diversity level of the whole elite pool is calculated as follow $Avg_{i,j} \frac{\|\vec{adn}(elite_i) - \vec{adn}(elite_j)\|}{\|\vec{bound}_{max} - \vec{bound}_{min}\|}$ where $\vec{adn}(elite_i)$ is the genes vector of the i -th elite entity, and \vec{bound}_{max} and \vec{bound}_{min} are the vector of maximum and minimum values of the genes.

Some explanation: $delta$ bias the mutation toward the direction that improved the result at previous step; in the pool of discarded entities high ranked ones tend to have few mutations and low ranked ones tend to have more mutation, this tends to cover any possibilities of evolution; entities newly entered in the elite pool tends to produce new entities near to them (in term of distance in the genes space), while older ones tend to produce more diverse new entities, thus the exploration of solution space occurs from the vicinity of newly better solutions toward larger areas; from the previous point, a good entity tends to create a lot of similar entity, which may lead to an elite pool saturated with very similar entities (inbreeding) from which the algorithm can't escape, this is prevented by the forced mutation of elites when the inbreeding level gets too high.

2 Interface

```
// ===== GENALG.H =====

#ifndef GENALG_H
#define GENALG_H

// ===== Include =====

#include <stdlib.h>
```

```

#include <stdio.h>
#include <math.h>
#include <string.h>
#include <stdbool.h>
#include "pberr.h"
#include "pbmath.h"
#include "gset.h"

// ===== Define =====

#define GENALG_NBENTITIES 100
#define GENALG_NBELITES 20

// ----- GenAlgAdn

// ===== Data structure =====

typedef struct GenAlg GenAlg;

typedef struct GenAlgAdn {
    // ID
    unsigned long int _id;
    // Age
    unsigned long int _age;
    // Adn for floating point value
    VecFloat* _adnF;
    // Delta Adn during mutation for floating point value
    VecFloat* _deltaAdnF;
    // Adn for integer point value
    VecShort* _adnI;
    // Value
    float _val;
} GenAlgAdn;

// ===== Functions declaration =====

// Create a new GenAlgAdn with ID 'id', 'lengthAdnF' and 'lengthAdnI'
// 'lengthAdnF' and 'lengthAdnI' must be greater than or equal to 0
GenAlgAdn* GenAlgAdnCreate(const int id, const int lengthAdnF,
    const int lengthAdnI);

// Free memory used by the GenAlgAdn 'that'
void GenAlgAdnFree(GenAlgAdn** that);

// Return the adn for floating point values of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
const VecFloat* GAAdnAdnF(const GenAlgAdn* const that);

// Return the delta of adn for floating point values of the
// GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
const VecFloat* GAAdnDeltaAdnF(const GenAlgAdn* const that);

// Return the adn for integer values of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
VecShort* GAAdnAdnI(const GenAlgAdn* const that);

```

```

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga' according to the type of the GenAlg
void GAAdnInit(const GenAlgAdn* const that, const GenAlg* ga);

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga', version used to calculate the parameters of a NeuraNet
void GAAdnInitNeuraNet(const GenAlgAdn* const that, const GenAlg* ga);

// Get the 'iGene'-th gene of the adn for floating point values of the
// GenAlgAdn 'that'
#ifdef BUILDMODE != 0
inline
#endif
float GAAdnGetGeneF(const GenAlgAdn* const that, const int iGene);

// Get the delta of the 'iGene'-th gene of the adn for floating point
// values of the GenAlgAdn 'that'
#ifdef BUILDMODE != 0
inline
#endif
float GAAdnGetDeltaGeneF(const GenAlgAdn* const that, const int iGene);

// Get the 'iGene'-th gene of the adn for int values of the
// GenAlgAdn 'that'
#ifdef BUILDMODE != 0
inline
#endif
int GAAdnGetGeneI(const GenAlgAdn* const that, const int iGene);

// Set the 'iGene'-th gene of the adn for floating point values of the
// GenAlgAdn 'that' to 'gene'
#ifdef BUILDMODE != 0
inline
#endif
void GAAdnSetGeneF(GenAlgAdn* const that, const int iGene,
    const float gene);

// Set the delta of the 'iGene'-th gene of the adn for floating point
// values of the GenAlgAdn 'that' to 'delta'
#ifdef BUILDMODE != 0
inline
#endif
void GAAdnSetDeltaGeneF(GenAlgAdn* const that, const int iGene,
    const float delta);

// Set the 'iGene'-th gene of the adn for int values of the
// GenAlgAdn 'that' to 'gene'
#ifdef BUILDMODE != 0
inline
#endif
void GAAdnSetGeneI(GenAlgAdn* const that, const int iGene,
    const short gene);

// Get the id of the GenAlgAdn 'that'
#ifdef BUILDMODE != 0
inline
#endif
unsigned long int GAAdnGetId(const GenAlgAdn* const that);

// Get the age of the GenAlgAdn 'that'
#ifdef BUILDMODE != 0

```

```

inline
#endif
unsigned long int GAAdnGetAge(const GenAlgAdn* const that);

// Get the value of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
float GAAdnGetVal(const GenAlgAdn* const that);

// Print the information about the GenAlgAdn 'that' on the
// stream 'stream'
void GAAdnPrintln(const GenAlgAdn* const that, FILE* const stream);

// Return true if the GenAlgAdn 'that' is new, i.e. is age equals 1
// Return false
#if BUILDMODE != 0
inline
#endif
bool GAAdnIsNew(const GenAlgAdn* const that);

// Copy the GenAlgAdn 'tho' into the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
void GAAdnCopy(GenAlgAdn* const that, const GenAlgAdn* const tho);

// ----- GenAlg

// ===== Define =====

#define GABestAdnF(that) GAAdnAdnF(GABestAdn(that))
#define GABestAdnI(that) GAAdnAdnI(GABestAdn(that))

// ===== Data structure =====

typedef enum GenAlgType {
    genAlgTypeDefault,
    genAlgTypeNeuraNet,
    genAlgTypeNeuraNetConv
} GenAlgType;

// Data used when GenAlg is applied to a NeuraNet
typedef struct GANeuraNet {
    // Nb of input, hidden and output of the NeuraNet
    int _nbIn;
    int _nbHid;
    int _nbOut;
    int _nbBaseConv;
    int _nbBaseCellConv;
} GANeuraNet;

typedef struct GenAlg {
    // GSet of GenAlgAdn, sortval == score so the head of the set is the
    // worst adn and the tail of the set is the best
    GSet* _adns;
    // Copy of the best adn
    GenAlgAdn* _bestAdn;
    // Type of the GenAlg
    GenAlgType _type;
    // Current epoch
    unsigned long int _curEpoch;

```

```

// Nb elite entities in population
int _nbElites;
// Id of the next new GenAlgAdn
unsigned long int _nextId;
// Length of adn for floating point value
const int _lengthAdnF;
// Length of adn for integer value
const int _lengthAdnI;
// Bounds (min, max) for floating point values adn
VecFloat2D* _boundsF;
// Bounds (min, max) for integer values adn
VecShort2D* _boundsI;
// Norm of the range value for adns (optimization for diversity
// calculation)
float _normRangeFloat;
float _normRangeInt;
// Data used if the GenAlg is applied to a NeuraNet
GANeuraNet _NNdata;
// Number of ktevent
unsigned long int _nbKTEvent;
} GenAlg;

// ===== Functions declaration =====

// Create a new GenAlg with 'nbEntities', 'nbElites', 'lengthAdnF'
// and 'lengthAdnI'
// 'nbEntities' must greater than 2
// 'nbElites' must greater than 1
// 'lengthAdnF' and 'lengthAdnI' must be greater than or equal to 0
GenAlg* GenAlgCreate(const int nbEntities, const int nbElites,
    const int lengthAdnF, const int lengthAdnI);

// Free memory used by the GenAlg 'that'
void GenAlgFree(GenAlg** that);

// Get the type of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
GenAlgType GAGetType(const GenAlg* const that);

// Set the type of the GenAlg 'that' to genAlgTypeNeuraNet, the GenAlg
// will be used with a NeuraNet having 'nbIn' inputs, 'nbHid' hidden
// values and 'nbOut' outputs
#if BUILDMODE != 0
inline
#endif
void GASetTypeNeuraNet(GenAlg* const that, const int nbIn,
    const int nbHid, const int nbOut);

// Set the type of the GenAlg 'that' to genAlgTypeNeuraNetConv,
// the GenAlg will be used with a NeuraNet having 'nbIn' inputs,
// 'nbHid' hidden values, 'nbOut' outputs, 'nbBaseConv' bases function
// dedicated to the convolution and 'nbBaseCellConv' bases function per cell of convolution
#if BUILDMODE != 0
inline
#endif
void GASetTypeNeuraNetConv(GenAlg* const that, const int nbIn,
    const int nbHid, const int nbOut, const int nbBaseConv,
    const int nbBaseCellConv);

// Return the GSet of the GenAlg 'that'

```

```

#if BUILDMODE != 0
inline
#endif
GSet* GAAdns(const GenAlg* const that);

// Return the nb of entities of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
int GAGetNbAdns(const GenAlg* const that);

// Return the nb of elites of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
int GAGetNbElites(const GenAlg* const that);

// Return the current epoch of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAGetCurEpoch(const GenAlg* const that);

// Return the number of KTEvent of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAGetNbKTEvent(const GenAlg* const that);

// Set the nb of entities of the GenAlg 'that' to 'nb'
// 'nb' must be greater than 1, if 'nb' is lower than the current nb
// of elite the number of elite is set to 'nb' - 1
void GASetNbEntities(GenAlg* const that, const int nb);

// Set the nb of elites of the GenAlg 'that' to 'nb'
// 'nb' must be greater than 0, if 'nb' is greater or equal to the
// current nb of entities the number of entities is set to 'nb' + 1
void GASetNbElites(GenAlg* const that, const int nb);

// Get the length of adn for floating point value
#if BUILDMODE != 0
inline
#endif
int GAGetLengthAdnFloat(const GenAlg* const that);

// Get the length of adn for integer value
#if BUILDMODE != 0
inline
#endif
int GAGetLengthAdnInt(const GenAlg* const that);

// Get the bounds for the 'iGene'-th gene of adn for floating point
// values
#if BUILDMODE != 0
inline
#endif
const VecFloat2D* GABoundsAdnFloat(const GenAlg* const that,
    const int iGene);

// Get the bounds for the 'iGene'-th gene of adn for integer values
#if BUILDMODE != 0
inline

```



```

#endif
const VecShort2D* GABoundsAdnInt(const GenAlg* const that,
    const int iGene);

// Set the bounds for the 'iGene'-th gene of adn for floating point
// values to a copy of 'bounds'
#if BUILDMODE != 0
inline
#endif
void GASetBoundsAdnFloat(GenAlg* const that, const int iGene,
    const VecFloat2D* const bounds);

// Set the bounds for the 'iGene'-th gene of adn for integer values
// to a copy of 'bounds'
#if BUILDMODE != 0
inline
#endif
void GASetBoundsAdnInt(GenAlg* const that, const int iGene,
    const VecShort2D* const bounds);

// Get the GenAlgAdn of the GenAlg 'that' currently at rank 'iRank'
#if BUILDMODE != 0
inline
#endif
GenAlgAdn* GAAdn(const GenAlg* const that, const int iRank);

// Init the GenAlg 'that'
// Must be called after the bounds have been set
// The random generator must have been initialised before calling this
// function
void GAINit(GenAlg* const that);

// Step an epoch for the GenAlg 'that' with the current ranking of
// GenAlgAdn
void GAStep(GenAlg* const that);

// Print the information about the GenAlg 'that' on the stream 'stream'
void GAPrintln(const GenAlg* const that, FILE* const stream);

// Print a summary about the elite entities of the GenAlg 'that'
// on the stream 'stream'
void GAEliteSummaryPrintln(const GenAlg* const that,
    FILE* const stream);

// Get the diversity of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
float GAGetDiversity(const GenAlg* const that);

// Function which return the JSON encoding of 'that'
JSONNode* GAEncodeAsJSON(const GenAlg* const that);

// Function which decode from JSON encoding 'json' to 'that'
bool GADecodeAsJSON(GenAlg** that, const JSONNode* const json);

// Load the GenAlg 'that' from the stream 'stream'
// If the GenAlg is already allocated, it is freed before loading
// Return true in case of success, else false
bool GALoad(GenAlg** that, FILE* const stream);

// Save the GenAlg 'that' to the stream 'stream'

```

```

// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true in case of success, else false
bool GASave(const GenAlg* const that, FILE* const stream,
            const bool compact);

// Set the value of the GenAlgAdn 'adn' of the GenAlg 'that' to 'val'
#if BUILDMODE != 0
inline
#endif
void GASetAdnValue(GenAlg* const that, GenAlgAdn* const adn,
                  const float val);

// Update the norm of the range value for adans of the GenAlg 'that'
void GAUpdateNormRange(GenAlg* const that);

// Reset the GenAlg 'that'
// Randomize all the gene except those of the first adn
void GAKTEvent(GenAlg* const that);

// Return the best adn of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
const GenAlgAdn* GABestAdn(const GenAlg* const that);

// ===== Polymorphism =====

// ===== Inliner =====

#if BUILDMODE != 0
#include "genalg-inline.c"
#endif

#endif

```

3 Code

3.1 genalg.c

```

// ===== GENALG.C =====

// ===== Include =====

#include "genalg.h"
#if BUILDMODE == 0
#include "genalg-inline.c"
#endif

// ----- GenAlgAdn

// ===== Functions declaration =====

// Get the diversity value of 'adnA' against 'adnB'
// The diversity is equal to
float GAAAdnGetDiversity(const GenAlgAdn* const adnA,
                        const GenAlgAdn* const adnB, const GenAlg* const ga);

```

```

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga'
void GAAdnInitDefault(const GenAlgAdn* const that, const GenAlg* ga);

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga', version used to calculate the parameters of a NeuraNet
void GAAdnInitNeuraNet(const GenAlgAdn* const that, const GenAlg* ga);

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga', version used to calculate the parameters of a NeuraNet
// with convolution
void GAAdnInitNeuraNetConv(const GenAlgAdn* const that,
    const GenAlg* const ga);

// ===== Functions implementation =====

// Create a new GenAlgAdn with ID 'id', 'lengthAdnF' and 'lengthAdnI'
// 'lengthAdnF' and 'lengthAdnI' must be greater than or equal to 0
GenAlgAdn* GenAlgAdnCreate(const int id, const int lengthAdnF,
    const int lengthAdnI) {
    #if BUILDMODE == 0
        if (lengthAdnF < 0) {
            GenAlgErr->_type = PBErrTypeInvalidArg;
            sprintf(GenAlgErr->_msg, "'lengthAdnF' is invalid (%d>=0)",
                lengthAdnF);
            PBErrCatch(GenAlgErr);
        }
        if (lengthAdnI < 0) {
            GenAlgErr->_type = PBErrTypeInvalidArg;
            sprintf(GenAlgErr->_msg, "'lengthAdnI' is invalid (%d>=0)",
                lengthAdnI);
            PBErrCatch(GenAlgErr);
        }
    #endif
    // Allocate memory
    GenAlgAdn* that = PBErrMalloc(GenAlgErr, sizeof(GenAlgAdn));
    // Set the properties
    that->_age = 1;
    that->_id = id;
    if (lengthAdnF > 0) {
        that->_adnF = VecFloatCreate(lengthAdnF);
        that->_deltaAdnF = VecFloatCreate(lengthAdnF);
    } else {
        that->_adnF = NULL;
        that->_deltaAdnF = NULL;
    }
    if (lengthAdnI > 0)
        that->_adnI = VecShortCreate(lengthAdnI);
    else
        that->_adnI = NULL;
    // Return the new GenAlgAdn
    return that;
}

// Free memory used by the GenAlgAdn 'that'
void GenAlgAdnFree(GenAlgAdn** that) {
    // Check the argument
    if (that == NULL || *that == NULL) return;
    // Free memory
    if ((*that)->_adnF != NULL)
        VecFree(&((*that)->_adnF));
}

```

```

    if ((*that)->_deltaAdnF != NULL)
        VecFree(&((*that)->_deltaAdnF));
    if ((*that)->_adnI != NULL)
        VecFree(&((*that)->_adnI));
    free(*that);
    // Set the pointer to null
    *that = NULL;
}

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga' according to the type of GenAlg
void GAAdnInit(const GenAlgAdn* const that, const GenAlg* const ga) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    switch (GAGetType(ga)) {
        case genAlgTypeNeuraNet:
            GAAdnInitNeuraNet(that, ga);
            break;
        case genAlgTypeNeuraNetConv:
            GAAdnInitNeuraNetConv(that, ga);
            break;
        case genAlgTypeDefault:
        default:
            GAAdnInitDefault(that, ga);
    }
}

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga'
void GAAdnInitDefault(const GenAlgAdn* const that,
    const GenAlg* const ga) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // For each floating point value gene
    for (int iGene = GAGetLengthAdnFloat(ga); iGene--;) {
        float min = VecGet(GABoundsAdnFloat(ga, iGene), 0);
        float max = VecGet(GABoundsAdnFloat(ga, iGene), 1);
        float val = min + (max - min) * rnd();
        VecSet(that->_adnF, iGene, val);
    }
    // For each integer value gene
    for (int iGene = GAGetLengthAdnInt(ga); iGene--;) {
        short min = VecGet(GABoundsAdnInt(ga, iGene), 0);
        short max = VecGet(GABoundsAdnInt(ga, iGene), 1);
        short val = (short)round((float)min + (float)(max - min) * rnd());
        VecSet(that->_adnI, iGene, val);
    }
}

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga', version used to calculate the parameters of a NeuraNet
// with convolution

```

```

void GAAdnInitNeuraNetConv(const GenAlgAdn* const that,
    const GenAlg* const ga) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // For each floating point value gene
    for (int iGene = GAGetLengthAdnFloat(ga); iGene--;) {
        float min = VecGet(GABoundsAdnFloat(ga, iGene), 0);
        float max = VecGet(GABoundsAdnFloat(ga, iGene), 1);
        float val = min + (max - min) * rnd();
        VecSet(that->_adnF, iGene, val);
    }
}

// Initialise randomly the genes of the GenAlgAdn 'that' of the
// GenAlg 'ga', version used to calculate the parameters of a NeuraNet
void GAAdnInitNeuraNet(const GenAlgAdn* const that, const GenAlg* ga) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // Init the base functions randomly
    // For each floating point value gene
    for (int iGene = GAGetLengthAdnFloat(ga); iGene--;) {
        float min = VecGet(GABoundsAdnFloat(ga, iGene), 0);
        float max = VecGet(GABoundsAdnFloat(ga, iGene), 1);
        float val = min + (max - min) * rnd();
        VecSet(that->_adnF, iGene, val);
    }
    // Init the links by ensuring there is at least one link reaching
    // each output and use inputs as start of the initial links
    // For each integer value gene
    int shiftOut = ga->_NNdata._nbIn + ga->_NNdata._nbHid;
    for (int iGene = 0; iGene < GAGetLengthAdnInt(ga); iGene += 3) {
        VecSet(that->_adnI, iGene, -1);
    }
    for (int iOut = 0; iOut < ga->_NNdata._nbOut; ++iOut) {
        // The base function is randomly choosen but can't be an
        // inactive link
        short min = 0;
        short max = VecGet(GABoundsAdnInt(ga, iOut * 3), 1);
        short val = (short)round((float)min + (float)(max - min) * rnd());
        VecSet(that->_adnI, iOut * 3, val);
        // The start of the link is randomly choosen amongst inputs
        min = 0;
        max = ga->_NNdata._nbIn - 1;
        val = (short)round((float)min + (float)(max - min) * rnd());
        VecSet(that->_adnI, iOut * 3 + 1, val);
        // The end of the link is choosen sequentially amongst outputs
        VecSet(that->_adnI, iOut * 3 + 2, iOut + shiftOut);
    }
}

// Print the information about the GenAlgAdn 'that' on the
// stream 'stream'

```

```

void GAAdnPrintln(const GenAlgAdn* const that, FILE* const stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (stream == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'stream' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    fprintf(stream, "id:%lu age:%lu", GAAdnGetId(that), GAAdnGetAge(that));
    fprintf(stream, "\n");
    fprintf(stream, "  adnF:");
    VecFloatPrint(GAAdnAdnF(that), stream, 6);
    fprintf(stream, "\n");
    fprintf(stream, "  deltaAdnF:");
    VecFloatPrint(GAAdnDeltaAdnF(that), stream, 6);
    fprintf(stream, "\n");
    fprintf(stream, "  adnI:");
    VecPrint(GAAdnAdnI(that), stream);
    fprintf(stream, "\n");
}

// ----- GenAlg

// ===== Functions declaration =====

// Select the rank of two parents for the SRM algorithm
// Return the ranks in 'parents', with parents[0] <= parents[1]
void GASelectParents(const GenAlg* const that, int* const parents);

// Set the genes of the entity at rank 'iChild' as a 50/50 mix of the
// genes of entities at ranks 'parents[0]' and 'parents[1]'
void GAReproduction(const GenAlg* const that, const int* const parents,
    const int iChild);

// Set the genes of the entity at rank 'iChild' as a 50/50 mix of the
// genes of entities at ranks 'parents[0]' and 'parents[1]'
void GAReproductionDefault(GenAlg* const that,
    const int* const parents, const int iChild);

// Set the genes of the adn at rank 'iChild' as a 50/50 mix of the
// genes of adns at ranks 'parents[0]' and 'parents[1]'
// This version is optimised to calculate the parameters of a NeuraNet
// with convolution by inheriting whole bases from parents
void GAReproductionNeuraNetConv(GenAlg* const that,
    const int* const parents, const int iChild);

// Set the genes of the entity at rank 'iChild' as a 50/50 mix of the
// genes of entities at ranks 'parents[0]' and 'parents[1]'
// This version is optimised to calculate the parameters of a NeuraNet
// by inheriting whole bases and links from parents
void GAReproductionNeuraNet(GenAlg* const that,
    const int* const parents, const int iChild);

// Router toward the appropriate Mute function according to the type
// of GenAlg
void GAMute(GenAlg* const that, const int* const parents,
    const int iChild);

```

```

// Mute the genes of the entity at rank 'iChild'
void GAMuteDefault(GenAlg* const that, const int* const parents,
    const int iChild);

// Mute the genes of the entity at rank 'iChild'
// This version is optimised to calculate the parameters of a NeuraNet
// by ensuring coherence in links: outputs have at least one link
// and there is no dead link
void GAMuteNeuraNet(GenAlg* const that, const int* const parents,
    const int iChild);

// Mute the genes of the entity at rank 'iChild'
// This version is optimised to calculate the parameters of a NeuraNet
// with convolution by muting bases function per cell
void GAMuteNeuraNetConv(GenAlg* const that, const int* const parents,
    const int iChild);

// ===== Functions implementation =====

// Create a new GenAlg with 'nbEntities', 'nbElites', 'lengthAdnF'
// and 'lengthAdnI'
// 'nbEntities' must be greater than 2
// 'nbElites' must be greater than 1
// 'lengthAdnF' and 'lengthAdnI' must be greater than or equal to 0
GenAlg* GenAlgCreate(const int nbEntities, const int nbElites,
    const int lengthAdnF, const int lengthAdnI) {
    // Allocate memory
    GenAlg* that = PBErrMalloc(GenAlgErr, sizeof(GenAlg));
    // Set the properties
    that->_type = genAlgTypeDefault;
    that->_adns = GSetCreate();
    that->_curEpoch = 0;
    that->_nbKTEvent = 0;
    that->_bestAdn = GenAlgAdnCreate(0, lengthAdnF, lengthAdnI);
    *(int*)&(that->_lengthAdnF) = lengthAdnF;
    *(int*)&(that->_lengthAdnI) = lengthAdnI;
    if (lengthAdnF > 0) {
        that->_boundsF =
            PBErrMalloc(GenAlgErr, sizeof(VecFloat2D) * lengthAdnF);
        for (int iGene = lengthAdnF; iGene--;)
            that->_boundsF[iGene] = VecFloatCreateStatic2D();
    } else
        that->_boundsF = NULL;
    if (lengthAdnI > 0) {
        that->_boundsI =
            PBErrMalloc(GenAlgErr, sizeof(VecShort2D) * lengthAdnI);
        for (int iGene = lengthAdnI; iGene--;)
            that->_boundsI[iGene] = VecShortCreateStatic2D();
    } else
        that->_boundsI = NULL;
    that->_normRangeFloat = 1.0;
    that->_normRangeInt = 1.0;
    that->_nbElites = 0;
    that->_nextId = 0;
    GSetNbEntities(that, nbEntities);
    GSetNbElites(that, nbElites);
    // Return the new GenAlg
    return that;
}

// Free memory used by the GenAlg 'that'

```

```

void GenAlgFree(GenAlg** that) {
    // Check the argument
    if (that == NULL || *that == NULL) return;
    // Free memory
    GSetIterForward iter = GSetIterForwardCreateStatic(GAAdns(*that));
    do {
        GenAlgAdn* gaEnt = GSetIterGet(&iter);
        GenAlgAdnFree(&gaEnt);
    } while (GSetIterStep(&iter));
    GSetFree(&((*that)->_adns));
    if ((*that)->_boundsF != NULL)
        free((*that)->_boundsF);
    if ((*that)->_boundsI != NULL)
        free((*that)->_boundsI);
    GenAlgAdnFree(&((*that)->_bestAdn));
    free(*that);
    // Set the pointer to null
    *that = NULL;
}

// Set the nb of entities of the GenAlg 'that' to 'nb'
// 'nb' must be greater than 1, if 'nb' is lower than the current nb
// of elite the number of elite is set to 'nb' - 1
void GSetNbEntities(GenAlg* const that, const int nb) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
        if (nb <= 1) {
            GenAlgErr->_type = PBErrTypeInvalidArg;
            sprintf(GenAlgErr->_msg, "'nb' is invalid (%d>1)", nb);
            PBErrCatch(GenAlgErr);
        }
    #endif
    while (GSetNbElem(GAAdns(that)) > nb) {
        GenAlgAdn* gaEnt = GSetPop(GAAdns(that));
        GenAlgAdnFree(&gaEnt);
    }
    while (GSetNbElem(GAAdns(that)) < nb) {
        GenAlgAdn* ent = GenAlgAdnCreate(that->_nextId++,
            GAGetLengthAdnFloat(that), GAGetLengthAdnInt(that));
        GSetPush(GAAdns(that), ent);
    }
    if (GAGetNbElites(that) >= nb)
        GSetNbElites(that, nb - 1);
}

// Set the nb of elites of the GenAlg 'that' to 'nb'
// 'nb' must be greater than 0, if 'nb' is greater or equal to the
// current nb of entities the number of entities is set to 'nb' + 1
void GSetNbElites(GenAlg* const that, const int nb) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
        if (nb <= 1) {
            GenAlgErr->_type = PBErrTypeInvalidArg;
            sprintf(GenAlgErr->_msg, "'nb' is invalid (%d>1)", nb);

```



```

        PBErCatch(GenAlgErr);
    }
#endif
    if (GAGetNbAdns(that) <= nb)
        GASetNbEntities(that, nb + 1);
    that->_nbElites = nb;
}

// Init the GenAlg 'that'
// Must be called after the bounds have been set
// The random generator must have been initialised before calling this
// function
void GAINit(GenAlg* const that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErCatch(GenAlgErr);
    }
#endif
    // For each adn
    GSetIterForward iter = GSetIterForwardCreateStatic(GAAdns(that));
    do {
        // Get the adn
        GenAlgAdn* adn = GSetIterGet(&iter);
        // Initialise randomly the genes of the adn
        GAAdnInit(adn, that);
    } while (GSetIterStep(&iter));
    GAAdnCopy(that->_bestAdn, GAAdn(that, 0));
}

// Reset the GenAlg 'that'
// Randomize all the gene except those of the best adn
void GAKTEvent(GenAlg* const that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErCatch(GenAlgErr);
    }
#endif
    ++(that->_nbKTEvent);
    GenAlgAdn* adn = GAAdn(that, 0);
    unsigned long int age = adn->_age;
    GAAdnCopy(adn, GABestAdn(that));
    adn->_age = age;
    int parents[2] = {0};
    GAMute(that, parents, 0);
    adn->_age = 1;
    for (int iEnt = 1; iEnt < GAGetNbAdns(that);
        ++iEnt) {
        GenAlgAdn* adn = GAAdn(that, iEnt);
        GAAdnInit(adn, that);
        adn->_age = 1;
        adn->_id = (that->_nextId)++;
    }
}

// Step an epoch for the GenAlg 'that' with the current ranking of
// GenAlgAdn
void GASTep(GenAlg* const that) {
#ifdef BUILDMODE == 0

```

```

    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    // Selection, Reproduction, Mutation
    // Ensure the set of adns is sorted
    GSetSort(GAAdns(that));
    // Update the best adn if necessary
    if (that->_curEpoch == 1 ||
        GAAdnGetVal(GAAdn(that, 0)) > GAAdnGetVal(GABestAdn(that))) {
        GAAdnCopy(that->_bestAdn, GAAdn(that, 0));
    }
    // Declare a variable to memorize the parents
    int parents[2];
    // Get the diversity level
    float diversity = GAGetDiversity(that);
    // Correct the diversity level with the age of the best adn
    //diversity *=
    //1.0 - fsquare((float)(GAAdnGetAge(GAAdn(that, 0))) / 1000.0);
    // If the diversity level is too low
    if (diversity < PBMath_EPSILON || GAAdnGetAge(GAAdn(that, 0)) > 200) {
        // Renew diversity by applying a KT event (in memory of
        // chickens' grand pa and grand ma)
        GAKTEvent(that);
    }
    // Else, the diversity level is ok
    } else {
        // For each adn which is an elite
        for (int iAdn = 0; iAdn < GAGetNbElites(that); ++iAdn) {
            // Increment age
            ++(GAAdn(that, iAdn)->_age);
        }
        // For each adn which is not an elite
        for (int iAdn = GAGetNbElites(that); iAdn < GAGetNbAdns(that);
            ++iAdn) {
            // Select two parents for this adn
            GASelectParents(that, parents);
            // Set the genes of the adn as a 50/50 mix of parents' genes
            GAREproduction(that, parents, iAdn);
            // Mute the genes of the adn
            GAMute(that, parents, iAdn);
        }
    }
    // Increment the number of epochs
    ++(that->_curEpoch);
}

// Select the rank of two parents for the SRM algorithm
// Return the ranks in 'parents', with parents[0] <= parents[1]
void GASelectParents(const GenAlg* const that, int* const parents) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
}

```

```

#endif
// Declare a variable to memorize the parents' rank
int p[2];
do {
    for (int i = 2; i--;)
        // p[i] below may be equal to the rank of the highest non elite
        // adn, but it's not a problem so leave it and let's call that
        // the Hawking radiation of this function in memory of this great
        // man.
        p[i] = (int)floor(rnd() * (float)GAGetNbElites(that));
} while (p[0] == p[1]);
// Memorize the sorted parents' rank
if (p[0] < p[1]) {
    parents[0] = p[0];
    parents[1] = p[1];
} else {
    parents[0] = p[1];
    parents[1] = p[0];
}
}

// Set the genes of the adn at rank 'iChild' as a 50/50 mix of the
// genes of adns at ranks 'parents[0]' and 'parents[1]'
void GAReproduction(GenAlg* const that,
    const int* const parents, const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    switch (GAGetType(that)) {
        case genAlgTypeNeuraNet:
            GAReproductionNeuraNet(that, parents, iChild);
            break;
        case genAlgTypeNeuraNetConv:
            GAReproductionNeuraNetConv(that, parents, iChild);
            break;
        case genAlgTypeDefault:
        default:
            GAReproductionDefault(that, parents, iChild);
    }
}

// Set the genes of the adn at rank 'iChild' as a 50/50 mix of the
// genes of adns at ranks 'parents[0]' and 'parents[1]'
// This version is optimised to calculate the parameters of a NeuraNet
// by inheriting whole bases and links from parents
void GAReproductionNeuraNet(GenAlg* const that,
    const int* const parents, const int iChild) {

```

```

#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the parents and child
    GenAlgAdn* parentA = GAAdn(that, parents[0]);
    GenAlgAdn* parentB = GAAdn(that, parents[1]);
    GenAlgAdn* child = GAAdn(that, iChild);
    // For each gene of the adn for floating point value
    for (int iGene = 0; iGene < GAGetLengthAdnFloat(that); iGene += 3) {
        // Get the gene from one parent or the other with equal
        // probability
        if (rnd() < 0.5) {
            for (int jGene = 3; jGene--;) {
                VecSet(child->_adnF, iGene + jGene,
                    VecGet(parentA->_adnF, iGene + jGene));
                VecSet(child->_deltaAdnF, iGene + jGene,
                    VecGet(parentA->_deltaAdnF, iGene + jGene));
            }
        } else {
            for (int jGene = 3; jGene--;) {
                VecSet(child->_adnF, iGene + jGene,
                    VecGet(parentB->_adnF, iGene + jGene));
                VecSet(child->_deltaAdnF, iGene + jGene,
                    VecGet(parentB->_deltaAdnF, iGene + jGene));
            }
        }
    }
    // For each gene of the adn for int value
    for (int iGene = 0; iGene < GAGetLengthAdnInt(that); iGene += 3) {
        // Get the gene from one parent or the other with equal probability
        if (rnd() < 0.5) {
            for (int jGene = 3; jGene--;)
                VecSet(child->_adnI, iGene + jGene,
                    VecGet(parentA->_adnI, iGene + jGene));
        } else {
            for (int jGene = 3; jGene--;)
                VecSet(child->_adnI, iGene + jGene,
                    VecGet(parentB->_adnI, iGene + jGene));
        }
    }
    // Reset the age of the child
    child->_age = 1;
    // Set the id of the child
    child->_id = (that->_nextId)++;
}

// Set the genes of the adn at rank 'iChild' as a 50/50 mix of the

```

```

// genes of adns at ranks 'parents[0]' and 'parents[1]'
// This version is optimised to calculate the parameters of a NeuraNet
// with convolution by inheriting whole bases from parents
void GAReproductionNeuraNetConv(GenAlg* const that,
    const int* const parents, const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the parents and child
    GenAlgAdn* parentA = GAAdn(that, parents[0]);
    GenAlgAdn* parentB = GAAdn(that, parents[1]);
    GenAlgAdn* child = GAAdn(that, iChild);
    // For each gene of the adn for floating point value of convolution
    // base functions
    for (int iGene = 0;
        iGene < that->_NNdata._nbBaseConv * 3;
        iGene += that->_NNdata._nbBaseCellConv * 3) {
        // Get the gene from one parent or the other with equal probability
        if (rnd() < 0.5) {
            for (int jGene = that->_NNdata._nbBaseCellConv * 3;
                jGene--;) {
                VecSet(child->_adnF, iGene + jGene,
                    VecGet(parentA->_adnF, iGene + jGene));
                VecSet(child->_deltaAdnF, iGene + jGene,
                    VecGet(parentA->_deltaAdnF, iGene + jGene));
            }
        } else {
            for (int jGene = that->_NNdata._nbBaseCellConv * 3;
                jGene--;) {
                VecSet(child->_adnF, iGene + jGene,
                    VecGet(parentB->_adnF, iGene + jGene));
                VecSet(child->_deltaAdnF, iGene + jGene,
                    VecGet(parentB->_deltaAdnF, iGene + jGene));
            }
        }
    }
    // For each gene of the adn for floating point value of convolution
    // base functions
    for (int iGene = that->_NNdata._nbBaseConv * 3;
        iGene < GAGetLengthAdnFloat(that); iGene += 3) {
        // Get the gene from one parent or the other with equal probability
        if (rnd() < 0.5) {
            for (int jGene = 3; --jGene;) {
                VecSet(child->_adnF, iGene + jGene,
                    VecGet(parentA->_adnF, iGene + jGene));
                VecSet(child->_deltaAdnF, iGene + jGene,
                    VecGet(parentA->_deltaAdnF, iGene + jGene));
            }
        }
    }
}

```

```

    }
} else {
    for (int jGene = 3; --jGene;) {
        VecSet(child->_adnF, iGene + jGene,
            VecGet(parentB->_adnF, iGene + jGene));
        VecSet(child->_deltaAdnF, iGene + jGene,
            VecGet(parentB->_deltaAdnF, iGene + jGene));
    }
}
}
// Reset the age of the child
child->_age = 1;
// Set the id of the child
child->_id = (that->_nextId)++;
}

// Set the genes of the adn at rank 'iChild' as a 50/50 mix of the
// genes of adns at ranks 'parents[0]' and 'parents[1]'
void GAReproductionDefault(GenAlg* const that,
    const int* const parents, const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the parents and child
    GenAlgAdn* parentA = GAAdn(that, parents[0]);
    GenAlgAdn* parentB = GAAdn(that, parents[1]);
    GenAlgAdn* child = GAAdn(that, iChild);
    // For each gene of the adn for floating point value
    for (int iGene = GAGetLengthAdnFloat(that); iGene--;) {
        // Get the gene from one parent or the other with equal probability
        if (rnd() < 0.5) {
            VecSet(child->_adnF, iGene, VecGet(parentA->_adnF, iGene));
            VecSet(child->_deltaAdnF, iGene,
                VecGet(parentA->_deltaAdnF, iGene));
        } else {
            VecSet(child->_adnF, iGene, VecGet(parentB->_adnF, iGene));
            VecSet(child->_deltaAdnF, iGene,
                VecGet(parentB->_deltaAdnF, iGene));
        }
    }
    // For each gene of the adn for int value
    for (int iGene = GAGetLengthAdnInt(that); iGene--;) {
        // Get the gene from one parent or the other with equal probability
        if (rnd() < 0.5)
            VecSet(child->_adnI, iGene, VecGet(parentA->_adnI, iGene));
        else
            VecSet(child->_adnI, iGene, VecGet(parentB->_adnI, iGene));
    }
}

```

```

    }
    // Reset the age of the child
    child->_age = 1;
    // Set the id of the child
    child->_id = (that->_nextId)++;
}

// Router toward the appropriate Mute function according to the type
// of GenAlg
void GAMute(GenAlg* const that, const int* const parents,
            const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
                iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    switch (GAGetType(that)) {
        case genAlgTypeNeuraNet:
            GAMuteNeuraNet(that, parents, iChild);
            break;
        case genAlgTypeNeuraNetConv:
            GAMuteNeuraNetConv(that, parents, iChild);
            break;
        case genAlgTypeDefault:
        default:
            GAMuteDefault(that, parents, iChild);
    }
}

// Mute the genes of the entity at rank 'iChild'
// This version is optimised to calculate the parameters of a NeuraNet
// by ensuring coherence in links: outputs have at least one link
// and there is no dead link
void GAMuteNeuraNet(GenAlg* const that, const int* const parents,
                    const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",

```

```

        iChild, GAGetNbAdns(that));
    PBErrCatch(GenAlgErr);
}
#endif
// Get the first parent and child
GenAlgAdn* parentA = GAAdn(that, parents[0]);
GenAlgAdn* child = GAAdn(that, iChild);
// Get the proba and amplitude of mutation
float probMute = sqrt(((float)iChild) / ((float)GAGetNbAdns(that)));
float amp = 1.0 - sqrt(1.0 / (float)(parentA->_age + 1));
probMute /= (float)(GAGetLengthAdnInt(that));
probMute += (float)(parentA->_age) / 10000.0;
// Ensure the proba is not null
if (probMute < PBMath_EPSILON)
    probMute = PBMath_EPSILON;
// Declare a variable to memorize if there has been mutation
bool hasMuted = false;
// Declare a variable to memorize the used values amongst input and
// hidden
int nbMaxUsedVal = that->_NNdata._nbIn + that->_NNdata._nbHid;
char* isUsed = PBErrMalloc(GenAlgErr, sizeof(char) * nbMaxUsedVal);
// Loop until there has been at least one mutation
do {
    // Reset the used values
    memset(isUsed, 0, sizeof(char) * nbMaxUsedVal);
    memset(isUsed, 1, sizeof(char) * that->_NNdata._nbIn);
    // For each gene of the adn for int value (links definitions)
    for (int iGene = 0; iGene < GAGetLengthAdnInt(that); iGene += 3) {
        // If the link mutes
        if (rnd() < probMute) {
            hasMuted = true;
            // If this link is currently inactivated
            if (GAAdnGetGeneI(child, iGene) == -1) {
                // Base function
                int iBase = (int)round((float)iGene / 3.0);
                GAAdnSetGeneI(child, iGene, iBase);
                // Input
                short min =
                    VecGet(GABoundsAdnInt(that, iGene + 1), 0);
                short max =
                    VecGet(GABoundsAdnInt(that, iGene + 1), 1);
                short val = min;
                // Ensure the input is a used value
                do {
                    val = (short)round((float)min +
                        (float)(max - min) * rnd());
                } while (isUsed[val] == 0);
                GAAdnSetGeneI(child, iGene + 1, val);
                // Output
                min = MAX(val, VecGet(GABoundsAdnInt(that, iGene + 2), 0));
                max = VecGet(GABoundsAdnInt(that, iGene + 2), 1);
                val = (short)round((float)min + (float)(max - min) * rnd());
                GAAdnSetGeneI(child, iGene + 2, val);
                if (val < nbMaxUsedVal)
                    isUsed[val] = 1;
            }
            // Else, this link is currently activated
        } else {
            // Choose between inactivation or mutation
            if (rnd() < 0.5) {
                // Inactivate the link
                GAAdnSetGeneI(child, iGene, -1);
            } else {

```



```

// Input
short min =
    VecGet(GABoundsAdnInt(that, iGene + 1), 0);
short max =
    VecGet(GABoundsAdnInt(that, iGene + 1), 1);
short val = min;
// Ensure the input is a used value
do {
    val = (short)round((float)min +
        (float)(max - min) * rnd());
} while (isUsed[val] == 0);
GAAdnSetGeneI(child, iGene + 1, val);
// Output
min = MAX(val, VecGet(GABoundsAdnInt(that, iGene + 2), 0));
max = VecGet(GABoundsAdnInt(that, iGene + 2), 1);
val = (short)round((float)min + (float)(max - min) * rnd());
GAAdnSetGeneI(child, iGene + 2, val);
if (val < nbMaxUsedVal)
    isUsed[val] = 1;
}
}
}
// Get the index of the base function
int baseFun = GAAdnGetGeneI(child, iGene);
// If the link is active
if (baseFun != -1) {
    // If the associated base function mutes
    if (rnd() < probbMute) {
        int baseFunGene = baseFun * 3;
        for (int jGene = 3; jGene--;) {
            // Get the bounds
            const VecFloat2D* const bounds =
                GABoundsAdnFloat(that, baseFunGene + jGene);
            // Declare a variable to memorize the previous value
            // of the gene
            float prevVal = GAAdnGetGeneF(child, baseFunGene + jGene);
            // Apply the mutation
            GAAdnSetGeneF(child, baseFunGene + jGene,
                GAAdnGetGeneF(child, baseFunGene + jGene) +
                (VecGet(bounds, 1) - VecGet(bounds, 0)) * amp *
                (rnd() - 0.5 +
                    GAAdnGetDeltaGeneF(child, baseFunGene + jGene)));
            // Keep the gene value in bounds
            while (GAAdnGetGeneF(child, baseFunGene + jGene) <
                VecGet(bounds, 0) ||
                GAAdnGetGeneF(child, baseFunGene + jGene) >
                VecGet(bounds, 1)) {
                if (GAAdnGetGeneF(child, baseFunGene + jGene) >
                    VecGet(bounds, 1))
                    GAAdnSetGeneF(child, baseFunGene + jGene,
                        2.0 * VecGet(bounds, 1) -
                        GAAdnGetGeneF(child, baseFunGene + jGene));
                else if (GAAdnGetGeneF(child, baseFunGene + jGene) <
                    VecGet(bounds, 0))
                    GAAdnSetGeneF(child, baseFunGene + jGene,
                        2.0 * VecGet(bounds, 0) -
                        GAAdnGetGeneF(child, baseFunGene + jGene));
            }
            // Update the deltaAdn
            GAAdnSetDeltaGeneF(child, baseFunGene + jGene,
                GAAdnGetGeneF(child, baseFunGene + jGene) - prevVal);
        }
    }
}

```

```

    }
    }
} while (hasMuted == false);
free(isUsed);
}

// Mute the genes of the entity at rank 'iChild'
void GAMuteDefault(GenAlg* const that, const int* const parents,
    const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the first parent and child
    GenAlgAdn* parentA = GAAdn(that, parents[0]);
    GenAlgAdn* child = GAAdn(that, iChild);
    // Get the proba amplitude of mutation
    float probMute = sqrt(((float)iChild) / ((float)GAGetNbAdns(that)));
    float amp = 1.0 - sqrt(1.0 / (float)(parentA->_age));
    probMute /= (float)(GAGetLengthAdnInt(that));
    probMute += (float)(parentA->_age) / 10000.0;
    if (probMute < PBMath_EPSILON)
        probMute = PBMath_EPSILON;
    bool hasMuted = false;
    do {
        // For each gene of the adn for floating point value
        for (int iGene = GAGetLengthAdnFloat(that); iGene--;) {
            // If this gene mutes
            if (rnd() < probMute) {
                hasMuted = true;
                // Get the bounds
                const VecFloat2D* const bounds = GABoundsAdnFloat(that, iGene);
                // Declare a variable to memorize the previous value of the gene
                float prevVal = GAAdnGetGeneF(child, iGene);
                // Apply the mutation
                GAAdnSetGeneF(child, iGene, GAAdnGetGeneF(child, iGene) +
                    (VecGet(bounds, 1) - VecGet(bounds, 0)) * amp *
                    (rnd() - 0.5 + GAAdnGetDeltaGeneF(child, iGene)));
                // Keep the gene value in bounds
                while (GAAdnGetGeneF(child, iGene) < VecGet(bounds, 0) ||
                    GAAdnGetGeneF(child, iGene) > VecGet(bounds, 1)) {
                    if (GAAdnGetGeneF(child, iGene) > VecGet(bounds, 1))
                        GAAdnSetGeneF(child, iGene,
                            2.0 * VecGet(bounds, 1) - GAAdnGetGeneF(child, iGene));
                    else if (GAAdnGetGeneF(child, iGene) < VecGet(bounds, 0))
                        GAAdnSetGeneF(child, iGene,
                            2.0 * VecGet(bounds, 0) - GAAdnGetGeneF(child, iGene));
                }
            }
        }
    } while (!hasMuted);
}

```

```

    }
    // Update the deltaAdn
    GAAdnSetDeltaGeneF(child, iGene,
        GAAdnGetGeneF(child, iGene) - prevVal);
}
}
// For each gene of the adn for int value
for (int iGene = GAGetLengthAdnInt(that); iGene--;) {
    // If this gene mutes
    if (rnd() < probMute) {
        hasMuted = true;
        // Get the bounds
        const VecShort2D* const boundsI = GABoundsAdnInt(that, iGene);
        VecFloat2D bounds = VecShortToFloat2D(boundsI);
        // Apply the mutation (as it is int value, ensure the amplitude
        // is big enough to have an effect
        float ampI = MIN(2.0,
            (float)(VecGet(&bounds, 1) - VecGet(&bounds, 0)) * amp);
        GAAdnSetGeneI(child, iGene, GAAdnGetGeneI(child, iGene) +
            (short)round(ampI * (rnd() - 0.5)));
        // Keep the gene value in bounds
        while (GAAdnGetGeneI(child, iGene) < VecGet(&bounds, 0) ||
            GAAdnGetGeneI(child, iGene) > VecGet(&bounds, 1)) {
            if (GAAdnGetGeneI(child, iGene) > VecGet(&bounds, 1))
                GAAdnSetGeneI(child, iGene,
                    2 * VecGet(&bounds, 1) - GAAdnGetGeneI(child, iGene));
            else if (GAAdnGetGeneI(child, iGene) < VecGet(&bounds, 0))
                GAAdnSetGeneI(child, iGene,
                    2 * VecGet(&bounds, 0) - GAAdnGetGeneI(child, iGene));
        }
    }
}
} while (hasMuted == false);
}

// Mute the genes of the entity at rank 'iChild'
// This version is optimised to calculate the parameters of a NeuraNet
// with convolution by muting bases function per cell
void GAMuteNeuraNetConv(GenAlg* const that, const int* const parents,
    const int iChild) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (parents == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'parents' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iChild < 0 || iChild >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'child' is invalid (0<=%d<=%d)",
            iChild, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the first parent and child
    GenAlgAdn* parentA = GAAdn(that, parents[0]);
    GenAlgAdn* child = GAAdn(that, iChild);
    // Get the proba amplitude of mutation

```

```

float probbMute = sqrt(((float)iChild) / ((float)GAGetNbAdns(that)));
float amp = 1.0 - sqrt(1.0 / (float)(parentA->_age));
probbMute /= (float)(GAGetLengthAdnInt(that));
probbMute += (float)(parentA->_age) / 10000.0;
if (probbMute < PBMath_EPSILON)
    probbMute = PBMath_EPSILON;
bool hasMuted = false;
do {
    // For each gene of the adn for floating point value
    for (int iGene = GAGetLengthAdnFloat(that); iGene--;) {
        // If this gene mutes
        if (rnd() < probbMute) {
            hasMuted = true;
            // Get the bounds
            const VecFloat2D* const bounds = GABoundsAdnFloat(that, iGene);
            // Declare a variable to memorize the previous value of the gene
            float prevVal = GAAdnGetGeneF(child, iGene);
            // Apply the mutation
            GAAdnSetGeneF(child, iGene, GAAdnGetGeneF(child, iGene) +
                (VecGet(bounds, 1) - VecGet(bounds, 0)) * amp *
                (rnd() - 0.5 + GAAdnGetDeltaGeneF(child, iGene)));
            // Keep the gene value in bounds
            while (GAAdnGetGeneF(child, iGene) < VecGet(bounds, 0) ||
                GAAdnGetGeneF(child, iGene) > VecGet(bounds, 1)) {
                if (GAAdnGetGeneF(child, iGene) > VecGet(bounds, 1))
                    GAAdnSetGeneF(child, iGene,
                        2.0 * VecGet(bounds, 1) - GAAdnGetGeneF(child, iGene));
                else if (GAAdnGetGeneF(child, iGene) < VecGet(bounds, 0))
                    GAAdnSetGeneF(child, iGene,
                        2.0 * VecGet(bounds, 0) - GAAdnGetGeneF(child, iGene));
            }
            // Update the deltaAdn
            GAAdnSetDeltaGeneF(child, iGene,
                GAAdnGetGeneF(child, iGene) - prevVal);
        }
    }
} while (hasMuted == false);
}

// Print the information about the GenAlg 'that' on the stream 'stream'
void GAPrintln(const GenAlg* const that, FILE* const stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (stream == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'stream' is null");
        PBErrCatch(GenAlgErr);
    }
}
#endif
fprintf(stream, "epoch:%lu\n", GAGetCurEpoch(that));
fprintf(stream, "%d entities, %d elites\n", GAGetNbAdns(that),
    GAGetNbElites(that));
GSetIterBackward iter = GSetIterBackwardCreateStatic(GAAdns(that));
int iEnt = 0;
do {
    GenAlgAdn* ent = GSetIterGet(&iter);
    fprintf(stream, "%#d value:%f ", iEnt,
        GSetIterGetElem(&iter)->_sortVal);

```

```

        if (iEnt < GAGetNbElites(that))
            fprintf(stream, "elite ");
        GAAdnPrintln(ent, stream);
        ++iEnt;
    } while (GSetIterStep(&iter));
}

// Print a summary about the elite entities of the GenAlg 'that'
// on the stream 'stream'
void GAEeliteSummaryPrintln(const GenAlg* const that,
    FILE* const stream) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
        if (stream == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'stream' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    GSetIterBackward iter = GSetIterBackwardCreateStatic(GAAdns(that));
    int iEnt = 0;
    GenAlgAdn* leader = GSetIterGet(&iter);
    fprintf(stream, "(age,val,div) ");
    do {
        GenAlgAdn* ent = GSetIterGet(&iter);
        fprintf(stream, "(%lu,%.3f,%.3f) ", GAAdnGetAge(ent),
            GSetIterGetElem(&iter)->_sortVal,
            GAAdnGetDiversity(ent, leader, that));
        ++iEnt;
    } while (GSetIterStep(&iter) && iEnt < GAGetNbElites(that));
    fprintf(stream, "\n");
}

// Update the norm of the range value for adans of the GenAlg 'that'
void GAUpdateNormRange(GenAlg* const that) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // If there are float adn
    if (GAGetLengthAdnFloat(that) > 0) {
        // Declare a vector to memorize the ranges in float gene values
        VecFloat* range = VecFloatCreate(GAGetLengthAdnFloat(that));
        // Calculate the ranges in gene values
        for (int iGene = GAGetLengthAdnFloat(that); iGene--;)
            VecSet(range, iGene,
                VecGet(GABoundsAdnFloat(that, iGene), 1) -
                VecGet(GABoundsAdnFloat(that, iGene), 0));
        // Calculate the norm of the range
        that->_normRangeFloat = VecNorm(range);
        // Free memory
        VecFree(&range);
    }

    // If there are int adn

```

```

    if (GAGetLengthAdnInt(that) > 0) {
        // Declare a vector to memorize the ranges in int gene values
        VecFloat* range = VecFloatCreate(GAGetLengthAdnInt(that));
        // Calculate the ranges in gene values
        for (int iGene = GAGetLengthAdnInt(that); iGene--;)
            VecSet(range, iGene,
                VecGet(GABoundsAdnInt(that, iGene), 1) -
                VecGet(GABoundsAdnInt(that, iGene), 0));
        // Calculate the norm of the range
        that->_normRangeInt = VecNorm(range);
        // Free memory
        VecFree(&range);
    }
}

// Get the diversity value of 'adnA' against 'adnB'
// The diversity is equal to
float GAAdnGetDiversity(const GenAlgAdn* const adnA,
    const GenAlgAdn* const adnB, const GenAlg* const ga) {
    #if BUILDMODE == 0
        if (adnA == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'adnA' is null");
            PBErrCatch(GenAlgErr);
        }
        if (adnB == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'adnB' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // Declare a variable to memorize the result
    float diversity = 0.0;
    // If there are adn for floating point values
    if (GAAdnAdnF(adnA) != NULL && GAAdnAdnF(adnB) != NULL) {
        // Get the difference in adn with the first entity
        VecFloat* diff =
            VecGetOp(GAAdnAdnF(adnA), 1.0, GAAdnAdnF(adnB), -1.0);
        // Calculate the diversity
        diversity += VecNorm(diff) / ga->_normRangeFloat;
        // Free memory
        VecFree(&diff);
    }
    // If there are adn for int values
    if (GAAdnAdnI(adnA) != NULL && GAAdnAdnI(adnB) != NULL) {
        // Get the difference in adn with the first entity
        VecShort* diffI =
            VecGetOp(GAAdnAdnI(adnA), 1, GAAdnAdnI(adnB), -1);
        VecFloat* diff = VecShortToFloat(diffI);
        // Calculate the diversity
        diversity += VecNorm(diff) / ga->_normRangeInt;
        // Free memory
        VecFree(&diffI);
        VecFree(&diff);
    }
    // Correct diversity if there was both float and int adns
    if (GAAdnAdnF(adnA) != NULL && GAAdnAdnF(adnB) != NULL &&
        GAAdnAdnI(adnA) != NULL && GAAdnAdnI(adnB) != NULL)
        diversity /= 2.0;
    // Return the result
    return diversity;
}

```

```

}

// Function which return the JSON encoding of 'that'
JSONNode* GAAdnEncodeAsJSON(const GenAlgAdn* const that,
    const float elo) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'that' is null");
        PBErrCatch(PBMathErr);
    }
#endif
    // Create the JSON structure
    JSONNode* json = JSONCreate();
    // Declare a buffer to convert value into string
    char val[100];
    // Encode the id
    sprintf(val, "%lu", that->_id);
    JSONAddProp(json, "_id", val);
    // Encode the age
    sprintf(val, "%lu", that->_age);
    JSONAddProp(json, "_age", val);
    // Encode the elo
    sprintf(val, "%f", elo);
    JSONAddProp(json, "_elo", val);
    // Encode the value
    sprintf(val, "%f", that->_val);
    JSONAddProp(json, "_val", val);
    // Encode the genes
    if (that->_adnF != NULL) {
        JSONAddProp(json, "_adnF", VecEncodeAsJSON(that->_adnF));
        JSONAddProp(json, "_deltaAdnF", VecEncodeAsJSON(that->_deltaAdnF));
    }
    if (that->_adnI != NULL)
        JSONAddProp(json, "_adnI", VecEncodeAsJSON(that->_adnI));
    // Return the created JSON
    return json;
}

// Function which return the JSON encoding of 'that'
JSONNode* GAEncodeAsJSON(const GenAlg* const that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'that' is null");
        PBErrCatch(PBMathErr);
    }
#endif
    // Create the JSON structure
    JSONNode* json = JSONCreate();
    // Declare a buffer to convert value into string
    char val[100];
    // Encode the type
    sprintf(val, "%d", GAGetType(that));
    JSONAddProp(json, "_type", val);
    switch (GAGetType(that)) {
        case genAlgTypeNeuraNet:
        case genAlgTypeNeuraNetConv:
            sprintf(val, "%d", that->_NNdata._nbIn);
            JSONAddProp(json, "NN_nbIn", val);
            sprintf(val, "%d", that->_NNdata._nbHid);
            JSONAddProp(json, "NN_nbHid", val);
    }
}

```

```

        sprintf(val, "%d", that->_NNdata._nbOut);
        JSONAddProp(json, "NN_nbOut", val);
        sprintf(val, "%d", that->_NNdata._nbBaseConv);
        JSONAddProp(json, "NN_nbBaseConv", val);
        sprintf(val, "%d", that->_NNdata._nbBaseCellConv);
        JSONAddProp(json, "NN_nbBaseCellConv", val);
        break;
    default:
        break;
}
// Encode the nb adns
sprintf(val, "%d", GAGetNbAdns(that));
JSONAddProp(json, "_nbAdns", val);
// Encode the nb elites
sprintf(val, "%d", GAGetNbElites(that));
JSONAddProp(json, "_nbElites", val);
// Encode the length adn float
sprintf(val, "%d", GAGetLengthAdnFloat(that));
JSONAddProp(json, "_lengthAdnF", val);
// Encode the length adn int
sprintf(val, "%d", GAGetLengthAdnInt(that));
JSONAddProp(json, "_lengthAdnI", val);
// Encode the epoch
sprintf(val, "%lu", GAGetCurEpoch(that));
JSONAddProp(json, "_curEpoch", val);
// Encode the next id
sprintf(val, "%lu", that->_nextId);
JSONAddProp(json, "_nextId", val);
// Encode the bounds
JSONArrayStruct setBoundFloat = JSONArrayStructCreateStatic();
if (GAGetLengthAdnFloat(that) > 0) {
    for (int iBound = 0; iBound < GAGetLengthAdnFloat(that); ++iBound)
        JSONArrayStructAdd(&setBoundFloat,
            VecEncodeAsJSON((VecFloat*)GABoundsAdnFloat(that, iBound)));
    JSONAddProp(json, "_boundFloat", &setBoundFloat);
}
JSONArrayStruct setBoundInt = JSONArrayStructCreateStatic();
if (GAGetLengthAdnInt(that) > 0) {
    for (int iBound = 0; iBound < GAGetLengthAdnInt(that); ++iBound)
        JSONArrayStructAdd(&setBoundInt,
            VecEncodeAsJSON((VecShort*)GABoundsAdnInt(that, iBound)));
    JSONAddProp(json, "_boundInt", &setBoundInt);
}
// Save the adns
JSONArrayStruct setAdn = JSONArrayStructCreateStatic();
for (int iEnt = 0; iEnt < GAGetNbAdns(that); ++iEnt) {
    GenAlgAdn* ent = GSetElemData(GSetElement(GAAdns(that), iEnt));
    float sortVal = GSetElemGetSortVal(GSetElement(GAAdns(that), iEnt));
    JSONArrayStructAdd(&setAdn, GAAdnEncodeAsJSON(ent, sortVal));
}
JSONAddProp(json, "_adns", &setAdn);
// Save the best adn
JSONAddProp(json, "_bestAdn",
    GAAdnEncodeAsJSON(GABestAdn(that), 0.0));
// Free memory
JSONArrayStructFlush(&setBoundFloat);
JSONArrayStructFlush(&setBoundInt);
JSONArrayStructFlush(&setAdn);
// Return the created JSON
return json;
}

```



```

// Function which decode from JSON encoding 'json' to 'that'
bool GAAdnDecodeAsJSON(GenAlgAdn** that, const JSONNode* const json) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'that' is null");
        PBErrCatch(PBMathErr);
    }
    if (json == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'json' is null");
        PBErrCatch(PBMathErr);
    }
#endif
    // If 'that' is already allocated
    if (*that != NULL)
        // Free memory
        GenAlgAdnFree(that);
    // Get the id from the JSON
    JSONNode* prop = JSONProperty(json, "_id");
    if (prop == NULL) {
        return false;
    }
    int id = strtoul(JSONLabel(JSONValue(prop, 0)), NULL, 10);
    // Get the lengthAdnF from the JSON
    int lengthAdnF = 0;
    prop = JSONProperty(json, "_adnF");
    if (prop != NULL) {
        JSONNode* subprop = JSONProperty(prop, "_dim");
        lengthAdnF = atoi(JSONLabel(JSONValue(subprop, 0)));
    }
    // Get the lengthAdnI from the JSON
    int lengthAdnI = 0;
    prop = JSONProperty(json, "_adnI");
    if (prop != NULL) {
        JSONNode* subprop = JSONProperty(prop, "_dim");
        lengthAdnI = atoi(JSONLabel(JSONValue(subprop, 0)));
    }
    // Allocate memory
    *that = GenAlgAdnCreate(id, lengthAdnF, lengthAdnI);
    // Get the age from the JSON
    prop = JSONProperty(json, "_age");
    if (prop == NULL) {
        return false;
    }
    (*that)->_age = strtoul(JSONLabel(JSONValue(prop, 0)), NULL, 10);
    // Get the adnF from the JSON
    prop = JSONProperty(json, "_adnF");
    if (prop != NULL) {
        if (!VecDecodeAsJSON(&((*that)->_adnF), prop)) {
            return false;
        }
        prop = JSONProperty(json, "_deltaAdnF");
        if (prop == NULL) {
            return false;
        }
        if (!VecDecodeAsJSON(&((*that)->_deltaAdnF), prop)) {
            return false;
        }
    }
    // Get the adnI from the JSON
    prop = JSONProperty(json, "_adnI");

```

```

    if (prop != NULL)
        if (!VecDecodeAsJSON(&((*that)->_adnI), prop)) {
            return false;
        }
    // Get the value
    prop = JSONProperty(json, "_val");
    if (prop == NULL) {
        return false;
    }
    (*that)->_val = atof(JSONLabel(JSONValue(prop, 0)));
    // Return the success code
    return true;
}

// Function which decode from JSON encoding 'json' to 'that'
bool GADecodeAsJSON(GenAlg** that, const JSONNode* const json) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'that' is null");
        PBErrCatch(PBMathErr);
    }
    if (json == NULL) {
        PBMathErr->_type = PBErrTypeNullPointer;
        sprintf(PBMathErr->_msg, "'json' is null");
        PBErrCatch(PBMathErr);
    }
#endif
    // If 'that' is already allocated
    if (*that != NULL)
        // Free memory
        GenAlgFree(that);
    // Decode the nb adns
    JSONNode* prop = JSONProperty(json, "_nbAdns");
    if (prop == NULL) {
        return false;
    }
    int nbAdns = atoi(JSONLabel(JSONValue(prop, 0)));
    // Decode the nb elites
    prop = JSONProperty(json, "_nbElites");
    if (prop == NULL) {
        return false;
    }
    int nbElites = atoi(JSONLabel(JSONValue(prop, 0)));
    // Decode the length adn float
    prop = JSONProperty(json, "_lengthAdnF");
    if (prop == NULL) {
        return false;
    }
    int lengthAdnF = atoi(JSONLabel(JSONValue(prop, 0)));
    // Decode the length adn int
    prop = JSONProperty(json, "_lengthAdnI");
    if (prop == NULL) {
        return false;
    }
    int lengthAdnI = atoi(JSONLabel(JSONValue(prop, 0)));
    // Allocate memory
    *that = GenAlgCreate(nbAdns, nbElites, lengthAdnF, lengthAdnI);
    // Decode the type
    prop = JSONProperty(json, "_type");
    if (prop == NULL) {
        return false;
    }

```

```

}
int type = atoi(JSONLabel(JSONValue(prop, 0)));
switch (type) {
case genAlgTypeNeuraNet:
case genAlgTypeNeuraNetConv:
    prop = JSONProperty(json, "NN_nbIn");
    if (prop == NULL) {
        return false;
    }
    int nbIn = atoi(JSONLabel(JSONValue(prop, 0)));
    prop = JSONProperty(json, "NN_nbOut");
    if (prop == NULL) {
        return false;
    }
    int nbOut = atoi(JSONLabel(JSONValue(prop, 0)));
    prop = JSONProperty(json, "NN_nbHid");
    if (prop == NULL) {
        return false;
    }
    int nbHid = atoi(JSONLabel(JSONValue(prop, 0)));
    prop = JSONProperty(json, "NN_nbBaseConv");
    if (prop == NULL) {
        return false;
    }
    int nbBaseConv = atoi(JSONLabel(JSONValue(prop, 0)));
    prop = JSONProperty(json, "NN_nbBaseCellConv");
    if (prop == NULL) {
        return false;
    }
    int nbBaseCellConv = atoi(JSONLabel(JSONValue(prop, 0)));
    GASetTypeNeuraNetConv(*that, nbIn, nbHid, nbOut, nbBaseConv,
        nbBaseCellConv);
    break;
default:
    break;
}
// Decode the epoch
prop = JSONProperty(json, "_curEpoch");
if (prop == NULL) {
    return false;
}
(*that)->_curEpoch =
    strtoul(JSONLabel(JSONValue(prop, 0)), NULL, 10);
// Decode the next id
prop = JSONProperty(json, "_nextId");
if (prop == NULL) {
    return false;
}
(*that)->_nextId = strtoul(JSONLabel(JSONValue(prop, 0)), NULL, 10);
// Decode the bounds
prop = JSONProperty(json, "_boundFloat");
if (prop != NULL) {
    if (JSONGetNbValue(prop) != GAGetLengthAdnFloat(*that))
        return false;
    for (int iBound = 0; iBound < GAGetLengthAdnFloat(*that); ++iBound) {
        JSONNode* val = JSONValue(prop, iBound);
        VecFloat2D* b = NULL;
        if (!VecDecodeAsJSON((VecFloat**) &b, val)) {
            return false;
        }
    }
    GASetBoundsAdnFloat(*that, iBound, b);
    VecFree((VecFloat**) &b);
}

```

```

    }
}
prop = JSONProperty(json, "_boundInt");
if (prop != NULL) {
    if (JSONGetNbValue(prop) != GAGetLengthAdnInt(*that))
        return false;
    for (int iBound = 0; iBound < GAGetLengthAdnInt(*that); ++iBound) {
        JSONNode* val = JSONValue(prop, iBound);
        VecShort2D* b = NULL;
        if (!VecDecodeAsJSON((VecShort**) &b, val)) {
            return false;
        }
        GAGetBoundsAdnInt(*that, iBound, b);
        VecFree((VecShort**) &b);
    }
}
// Upadte the norm of the range values
GAUpdateNormRange(*that);
// Decode the adns
prop = JSONProperty(json, "_adns");
if (prop == NULL) {
    return false;
}
if (JSONGetNbValue(prop) != GAGetNbAdns(*that))
    return false;
for (int iEnt = 0; iEnt < GAGetNbAdns(*that); ++iEnt) {
    JSONNode* val = JSONValue(prop, iEnt);
    if (!GAAdnDecodeAsJSON(
        (GenAlgAdn**) &(GSetElement(GAAdns(*that), iEnt)->_data), val)) {
        return false;
    }
}
// Decode the best adn
prop = JSONProperty(json, "_bestAdn");
if (prop == NULL) {
    return false;
}
if (!GAAdnDecodeAsJSON((GenAlgAdn**) &((*that)->_bestAdn), prop)) {
    return false;
}

// Return the success code
return true;
}

// Load the GenAlg 'that' from the stream 'stream'
// If the GenAlg is already allocated, it is freed before loading
// Return true in case of success, else false
bool GALoad(GenAlg** that, FILE* const stream) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
        if (stream == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'stream' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    // Declare a json to load the encoded data

```

```

JSONNode* json = JSONCreate();
// Load the whole encoded data
if (!JSONLoad(json, stream)) {
    return false;
}
// Decode the data from the JSON
if (!GADecodeAsJSON(that, json)) {
    return false;
}
// Free the memory used by the JSON
JSONFree(&jjson);
// Return the success code
return true;
}

// Save the GenAlg 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true in case of success, else false
bool GASave(const GenAlg* const that, FILE* const stream,
const bool compact) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (stream == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'stream' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    // Get the JSON encoding
    JSONNode* json = GAEncodeAsJSON(that);
    // Save the JSON
    if (!JSONSave(json, stream, compact)) {
        return false;
    }
    // Free memory
    JSONFree(&jjson);
    // Return success code
    return true;
}

```

3.2 genalg-inline.c

```

// ===== GENALG-INLINE.C =====

// ----- GenAlgAdn

// ===== Functions implementation =====

// Return the adn for floating point values of the GenAlgAdn 'that'
#ifdef BUILDMODE != 0
inline
#endif
const VecFloat* GAAAdnAdnF(const GenAlgAdn* const that) {
#ifdef BUILDMODE == 0

```

```

    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_adnF;
}

// Return the delta of adn for floating point values of the
// GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
const VecFloat* GAAdnDeltaAdnF(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_deltaAdnF;
}

// Return the adn for integer values of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
VecShort* GAAdnAdnI(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_adnI;
}

// Get the 'iGene'-th gene of the adn for floating point values of the
// GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
float GAAdnGetGeneF(const GenAlgAdn* const that, const int iGene) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return VecGet(that->_adnF, iGene);
}

// Get the delta of the 'iGene'-th gene of the adn for floating point
// values of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
float GAAdnGetDeltaGeneF(const GenAlgAdn* const that, const int iGene) {

```

```

#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
return VecGet(that->_deltaAdnF, iGene);
}

// Get the 'iGene'-th gene of the adn for int values of the
// GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
int GAAdnGetGeneI(const GenAlgAdn* const that, const int iGene) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
return VecGet(that->_adnI, iGene);
}

// Set the 'iGene'-th gene of the adn for floating point values of the
// GenAlgAdn 'that' to 'gene'
#if BUILDMODE != 0
inline
#endif
void GAAdnSetGeneF(GenAlgAdn* const that, const int iGene,
    const float gene) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
VecSet(that->_adnF, iGene, gene);
}

// Set the delta of the 'iGene'-th gene of the adn for floating point
// values of the GenAlgAdn 'that' to 'delta'
#if BUILDMODE != 0
inline
#endif
void GAAdnSetDeltaGeneF(GenAlgAdn* const that, const int iGene,
    const float delta) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
VecSet(that->_deltaAdnF, iGene, delta);
}

// Set the 'iGene'-th gene of the adn for int values of the
// GenAlgAdn 'that' to 'gene'

```

```

#if BUILDMODE != 0
inline
#endif
void GAAdnSetGeneI(GenAlgAdn* const that, const int iGene,
    const short gene) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    VecSet(that->_adnI, iGene, gene);
}

// Get the id of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAAdnGetId(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_id;
}

// Get the age of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAAdnGetAge(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_age;
}

// Get the value of the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
float GAAdnGetVal(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_val;
}

// Return true if the GenAlgAdn 'that' is new, i.e. is age equals 1
// Return false

```



```

#if BUILDMODE != 0
inline
#endif
bool GAAdnIsNew(const GenAlgAdn* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    return (that->_age == 1);
}

// Copy the GenAlgAdn 'tho' into the GenAlgAdn 'that'
#if BUILDMODE != 0
inline
#endif
void GAAdnCopy(GenAlgAdn* const that, const GenAlgAdn* const tho) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
    if (tho == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'tho' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    that->_id = tho->_id;
    that->_age = tho->_age;
    that->_val = tho->_val;
    VecCopy(that->_adnF, tho->_adnF);
    VecCopy(that->_deltaAdnF, tho->_deltaAdnF);
    VecCopy(that->_adnI, tho->_adnI);
}

// ----- GenAlg

// ===== Functions implementation =====

// Get the type of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
GenAlgType GAGetType(const GenAlg* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    return that->_type;
}

// Set the type of the GenAlg 'that' to genAlgTypeNeuraNet, the GenAlg
// will be used with a NeuraNet having 'nbIn' inputs, 'nbHid' hidden
// values and 'nbOut' outputs
#if BUILDMODE != 0

```

```

inline
#endif
void GASetTypeNeuraNet(GenAlg* const that, const int nbIn,
    const int nbHid, const int nbOut) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    if (GAGetLengthAdnFloat(that) != GAGetLengthAdnInt(that)) {
        GenAlgErr->_type = PErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "Must have the same nb of bases and links");
        PErrCatch(GenAlgErr);
    }
    that->_type = genAlgTypeNeuraNet;
    that->_NNdata._nbIn = nbIn;
    that->_NNdata._nbHid = nbHid;
    that->_NNdata._nbOut = nbOut;
    that->_NNdata._nbBaseConv = 0;
}

// Set the type of the GenAlg 'that' to genAlgTypeNeuraNetConv,
// the GenAlg will be used with a NeuraNet having 'nbIn' inputs,
// 'nbHid' hidden values, 'nbOut' outputs, 'nbBaseConv' bases function
// dedicated to the convolution and 'nbBaseCellConv' bases function per cell of convolution
#ifdef BUILDMODE != 0
inline
#endif
void GASetTypeNeuraNetConv(GenAlg* const that, const int nbIn,
    const int nbHid, const int nbOut, const int nbBaseConv,
    const int nbBaseCellConv) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    if (GAGetLengthAdnFloat(that) != GAGetLengthAdnInt(that)) {
        GenAlgErr->_type = PErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "Must have the same nb of bases and links");
        PErrCatch(GenAlgErr);
    }
    that->_type = genAlgTypeNeuraNet;
    that->_NNdata._nbIn = nbIn;
    that->_NNdata._nbHid = nbHid;
    that->_NNdata._nbOut = nbOut;
    that->_NNdata._nbBaseConv = nbBaseConv;
    that->_NNdata._nbBaseCellConv = nbBaseCellConv;
}

// Return the GSet of the GenAlg 'that'
#ifdef BUILDMODE != 0
inline
#endif
GSet* GAAdns(const GenAlg* const that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
    }

```

```

        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_adns;
}

// Return the nb of entities of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
int GAGetNbAdns(const GenAlg* const that) {
    if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    return GSetNbElem(that->_adns);
}

// Return the nb of elites of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
int GAGetNbElites(const GenAlg* const that) {
    if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    return that->_nbElites;
}

// Return the current epoch of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAGetCurEpoch(const GenAlg* const that) {
    if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    #endif
    return that->_curEpoch;
}

// Return the number of KTEvent of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
unsigned long int GAGetNbKTEvent(const GenAlg* const that) {
    if BUILDMODE == 0
        if (that == NULL) {
            GenAlgErr->_type = PBErrTypeNullPointer;
            sprintf(GenAlgErr->_msg, "'that' is null");
            PBErrCatch(GenAlgErr);
        }
    }
}

```

```

#endif
    return that->_nbKTEvent;
}

// Get the length of adn for floating point value
#if BUILDMODE != 0
inline
#endif
int GAGetLengthAdnFloat(const GenAlg* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_lengthAdnF;
}

// Get the length of adn for integer value
#if BUILDMODE != 0
inline
#endif
int GAGetLengthAdnInt(const GenAlg* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_lengthAdnI;
}

// Set the bounds for the 'iGene'-th gene of adn for floating point
// values to a copy of 'bounds'
#if BUILDMODE != 0
inline
#endif
void GASetBoundsAdnFloat(GenAlg* const that, const int iGene,
    const VecFloat2D* const bounds) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (bounds == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'bounds' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iGene < 0 || iGene >= that->_lengthAdnF) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'iGene' is invalid (0<=%d<=%d)",
            iGene, that->_lengthAdnF);
        PBErrCatch(GenAlgErr);
    }
#endif
    VecCopy(that->_boundsF + iGene, bounds);
    GAUpdateNormRange(that);
}

```

```

}

// Set the bounds for the 'iGene'-th gene of adn for integer values
// to a copy of 'bounds'
#if BUILDMODE != 0
inline
#endif
void GASetBoundsAdnInt(GenAlg* const that, const int iGene,
    const VecShort2D* const bounds) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (bounds == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'bounds' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iGene < 0 || iGene >= that->_lengthAdnI) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'iGene' is invalid (0<=%d<%d)",
            iGene, that->_lengthAdnI);
        PBErrCatch(GenAlgErr);
    }
#endif
    VecCopy(that->_boundsI + iGene, bounds);
    GAUpdateNormRange(that);
}

// Get the bounds for the 'iGene'-th gene of adn for floating point
// values
#if BUILDMODE != 0
inline
#endif
const VecFloat2D* GABoundsAdnFloat(const GenAlg* const that,
    const int iGene) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iGene < 0 || iGene >= that->_lengthAdnF) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'iGene' is invalid (0<=%d<%d)",
            iGene, that->_lengthAdnF);
        PBErrCatch(GenAlgErr);
    }
#endif
    return that->_boundsF + iGene;
}

// Get the bounds for the 'iGene'-th gene of adn for integer values
#if BUILDMODE != 0
inline
#endif
const VecShort2D* GABoundsAdnInt(const GenAlg* const that,
    const int iGene) {
#if BUILDMODE == 0
    if (that == NULL) {

```

```

    GenAlgErr->_type = PBErrTypeNullPointer;
    sprintf(GenAlgErr->_msg, "'that' is null");
    PBErrCatch(GenAlgErr);
}
if (iGene < 0 || iGene >= that->_lengthAdnI) {
    GenAlgErr->_type = PBErrTypeInvalidArg;
    sprintf(GenAlgErr->_msg, "'iGene' is invalid (0<=%d<=%d)",
        iGene, that->_lengthAdnI);
    PBErrCatch(GenAlgErr);
}
#endif
return that->_boundsI + iGene;
}

// Get the GenAlgAdn of the GenAlg 'that' currently at rank 'iRank'
// (0 is the best adn)
#if BUILDMODE != 0
inline
#endif
GenAlgAdn* GAAdn(const GenAlg* const that, const int iRank) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (iRank < 0 || iRank >= GAGetNbAdns(that)) {
        GenAlgErr->_type = PBErrTypeInvalidArg;
        sprintf(GenAlgErr->_msg, "'iRank' is invalid (0<=%d<=%d)",
            iRank, GAGetNbAdns(that));
        PBErrCatch(GenAlgErr);
    }
#endif
    return (GenAlgAdn*)GSetGet(that->_adns,
        GSetNbElem(that->_adns) - iRank - 1);
}

// Set the value of the GenAlgAdn 'adn' of the GenAlg 'that' to 'val'
#if BUILDMODE != 0
inline
#endif
void GASetAdnValue(GenAlg* const that, GenAlgAdn* const adn,
    const float val) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PBErrCatch(GenAlgErr);
    }
    if (adn == NULL) {
        GenAlgErr->_type = PBErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'adn' is null");
        PBErrCatch(GenAlgErr);
    }
#endif
    // Set the value
    adn->_val = val;
    GSetElemSetSortVal((GSetElem*)GSetFirstElem(GAAdns(that), adn), val);
}

// Get the diversity of the GenAlg 'that'
#if BUILDMODE != 0

```

```

inline
#endif
float GAGetDiversity(const GenAlg* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    float diversity =
        GAAdn(that, 0)->_val - GAAdn(that, GAGetNbElites(that) - 1)->_val;
    return diversity;
}

// Return the best adn of the GenAlg 'that'
#if BUILDMODE != 0
inline
#endif
const GenAlgAdn* GABestAdn(const GenAlg* const that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GenAlgErr->_type = PErrTypeNullPointer;
        sprintf(GenAlgErr->_msg, "'that' is null");
        PErrCatch(GenAlgErr);
    }
#endif
    return that->_bestAdn;
}

```

4 Makefile

```

# Build mode
# 0: development (max safety, no optimisation)
# 1: release (min safety, optimisation)
# 2: fast and furious (no safety, optimisation)
BUILD_MODE?=1

all: main

# Makefile definitions
MAKEFILE_INC=../PMake/Makefile.inc
include $(MAKEFILE_INC)

# Rules to make the executable
repo=genalg
$($(repo)_EXENAME): \
$($(repo)_EXENAME).o \
$($(repo)_EXE_DEP) \
$($(repo)_DEP)
$(COMPILER) 'echo "$($(repo)_EXE_DEP) $($(repo)_EXENAME).o" | tr ' ' '\n' | sort -u' $(LINK_ARG) $($(repo)_LINK_ARG)

$($(repo)_EXENAME).o: \
$($(repo)_DIR)/$($(repo)_EXENAME).c \
$($(repo)_INC_H_EXE) \
$($(repo)_EXE_DEP)
$(COMPILER) $(BUILD_ARG) $($(repo)_BUILD_ARG) 'echo "$($(repo)_INC_DIR)" | tr ' ' '\n' | sort -u' -c $($(repo)_DIR)/

```

5 Unit tests

```
#include <stdlib.h>
#include <stdio.h>
#include <time.h>
#include <string.h>
#include <time.h>
#include <unistd.h>
#include <sys/time.h>
#include "genalg.h"

#define RANDOMSEED 2

void UnitTestGenAlgAdnCreateFree() {
    unsigned long int id = 1;
    int lengthAdnF = 2;
    int lengthAdnI = 3;
    GenAlgAdn* ent = GenAlgAdnCreate(id, lengthAdnF, lengthAdnI);
    if (ent->_age != 1 ||
        ent->_id != id ||
        VecGetDim(ent->_adnF) != lengthAdnF ||
        VecGetDim(ent->_deltaAdnF) != lengthAdnF ||
        VecGetDim(ent->_adnI) != lengthAdnI) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GenAlgAdnCreate failed");
        PBErrCatch(GenAlgErr);
    }
    GenAlgAdnFree(&ent);
    if (ent != NULL) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GenAlgAdnFree failed");
        PBErrCatch(GenAlgErr);
    }
    printf("UnitTestGenAlgAdnCreateFree OK\n");
}

void UnitTestGenAlgAdnGetSet() {
    unsigned long int id = 1;
    int lengthAdnF = 2;
    int lengthAdnI = 3;
    GenAlgAdn* ent = GenAlgAdnCreate(id, lengthAdnF, lengthAdnI);
    if (GAAdnAdnF(ent) != ent->_adnF) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAAdnAdnF failed");
        PBErrCatch(GenAlgErr);
    }
    if (GAAdnDeltaAdnF(ent) != ent->_deltaAdnF) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAAdnDeltaAdnF failed");
        PBErrCatch(GenAlgErr);
    }
    if (GAAdnAdnI(ent) != ent->_adnI) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAAdnAdnI failed");
        PBErrCatch(GenAlgErr);
    }
    GAAdnSetGeneF(ent, 0, 1.0);
    if (ISEQUALF(VecGet(ent->_adnF, 0), 1.0) == false) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAAdnSetGeneF failed");
        PBErrCatch(GenAlgErr);
    }
}
```



```

}
if (ISEQUALF(GAAdnGetGeneF(ent, 0), 1.0) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetGeneF failed");
    PBErrCatch(GenAlgErr);
}
GAAdnSetDeltaGeneF(ent, 0, 2.0);
if (ISEQUALF(VecGet(ent->_deltaAdnF, 0), 2.0) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnSetDeltaGeneF failed");
    PBErrCatch(GenAlgErr);
}
if (ISEQUALF(GAAdnGetDeltaGeneF(ent, 0), 2.0) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetDeltaGeneF failed");
    PBErrCatch(GenAlgErr);
}
GAAdnSetGeneI(ent, 0, 3);
if (VecGet(ent->_adnI, 0) != 3) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnSetGeneI failed");
    PBErrCatch(GenAlgErr);
}
if (GAAdnGetGeneI(ent, 0) != 3) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetGeneI failed");
    PBErrCatch(GenAlgErr);
}
if (GAAdnGetAge(ent) != 1) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetAge failed");
    PBErrCatch(GenAlgErr);
}
ent->_val = 2.0;
if (ISEQUALF(GAAdnGetVal(ent), 2.0) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetVal failed");
    PBErrCatch(GenAlgErr);
}
if (GAAdnGetId(ent) != id) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnGetId failed");
    PBErrCatch(GenAlgErr);
}
if (GAAdnIsNew(ent) != true) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnIsNew failed");
    PBErrCatch(GenAlgErr);
}
ent->_age = 2;
if (GAAdnIsNew(ent) != false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnIsNew failed");
    PBErrCatch(GenAlgErr);
}
GenAlgAdnFree(&ent);
printf("UnitTestGenAlgAdnGetSet OK\n");
}

void UnitTestGenAlgAdnInit() {
    srandom(5);
    unsigned long int id = 1;

```

```

int lengthAdnF = 2;
int lengthAdnI = 2;
GenAlgAdn* ent = GenAlgAdnCreate(id, lengthAdnF, lengthAdnI);
GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
    lengthAdnF, lengthAdnI);
VecFloat2D boundsF = VecFloatCreateStatic2D();
VecShort2D boundsI = VecShortCreateStatic2D();
VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
GASetBoundsAdnFloat(ga, 0, &boundsF);
GASetBoundsAdnFloat(ga, 1, &boundsF);
GASetBoundsAdnInt(ga, 0, &boundsI);
GASetBoundsAdnInt(ga, 1, &boundsI);
GAAdnInit(ent, ga);
if (ISEQUALF(VecGet(ent->_adnF, 0), -0.907064) == false ||
    ISEQUALF(VecGet(ent->_adnF, 1), -0.450509) == false ||
    VecGet(ent->_adnI, 0) != 2 ||
    VecGet(ent->_adnI, 1) != 10) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAAdnInit failed");
    PBErrCatch(GenAlgErr);
}
GenAlgFree(&ga);
GenAlgAdnFree(&ent);
printf("UnitTestGenAlgAdnInit OK\n");
}

void UnitTestGenAlgAdn() {
    UnitTestGenAlgAdnCreateFree();
    UnitTestGenAlgAdnGetSet();
    UnitTestGenAlgAdnInit();
    printf("UnitTestGenAlgAdn OK\n");
}

void UnitTestGenAlgCreateFree() {
    int lengthAdnF = 2;
    int lengthAdnI = 3;
    GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
        lengthAdnF, lengthAdnI);
    if (ga->_type != genAlgTypeDefault ||
        ga->_curEpoch != 0 ||
        ga->_nbKTEvent != 0 ||
        ga->_nextId != GENALG_NBENTITIES ||
        ga->_nbElites != GENALG_NBELITES ||
        ga->_lengthAdnF != lengthAdnF ||
        ga->_lengthAdnI != lengthAdnI ||
        GSetNbElem(GAAdns(ga)) != GENALG_NBENTITIES) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GenAlgCreate failed");
        PBErrCatch(GenAlgErr);
    }
    GenAlgFree(&ga);
    if (ga != NULL) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GenAlgFree failed");
        PBErrCatch(GenAlgErr);
    }
    printf("UnitTestGenAlgCreateFree OK\n");
}

void UnitTestGenAlgGetSet() {
    int lengthAdnF = 2;

```

```

int lengthAdnI = 3;
GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
    lengthAdnF, lengthAdnI);
if (GAGetType(ga) != ga->_type) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetType failed");
    PBErrCatch(GenAlgErr);
}
if (GAAdns(ga) != ga->_adns) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAElorank failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetNbAdns(ga) != GENALG_NBENTITIES) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetNbAdns failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetNbElites(ga) != GENALG_NBELITES) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetNbElites failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetCurEpoch(ga) != 0) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetCurEpoch failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetNbKTEvent(ga) != 0) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetNbKTEvent failed");
    PBErrCatch(GenAlgErr);
}
GASetNbEntities(ga, 10);
if (GAGetNbAdns(ga) != 10 ||
    GAGetNbElites(ga) != 9 ||
    GSetNbElem(GAAdns(ga)) != 10) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetNbEntities failed");
    PBErrCatch(GenAlgErr);
}
GASetNbElites(ga, 20);
if (GAGetNbAdns(ga) != 21 ||
    GAGetNbElites(ga) != 20 ||
    GSetNbElem(GAAdns(ga)) != 21) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetNbElites failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetLengthAdnFloat(ga) != lengthAdnF) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetLengthAdnFloat failed");
    PBErrCatch(GenAlgErr);
}
if (GAGetLengthAdnInt(ga) != lengthAdnI) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GAGetLengthAdnInt failed");
    PBErrCatch(GenAlgErr);
}
if (GABoundsAdnFloat(ga, 1) != ga->_boundsF + 1) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GABoundsAdnFloat failed");
}

```

```

    PBErCatch(GenAlgErr);
}
VecFloat2D boundsF = VecFloatCreateStatic2D();
VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
GASetBoundsAdnFloat(ga, 1, &boundsF);
if (VecIsEqual(GABoundsAdnFloat(ga, 1), &boundsF) == false) {
    GenAlgErr->_type = PBErTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetBoundsAdnFloat failed");
    PBErCatch(GenAlgErr);
}
VecShort2D boundsS = VecShortCreateStatic2D();
VecSet(&boundsS, 0, -1); VecSet(&boundsS, 1, 1);
GASetBoundsAdnInt(ga, 1, &boundsS);
if (VecIsEqual(GABoundsAdnInt(ga, 1), &boundsS) == false) {
    GenAlgErr->_type = PBErTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetBoundsAdnInt failed");
    PBErCatch(GenAlgErr);
}
if (GABoundsAdnInt(ga, 1) != ga->_boundsI + 1) {
    GenAlgErr->_type = PBErTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GABoundsAdnInt failed");
    PBErCatch(GenAlgErr);
}
GASetAdnValue(ga, GAAdn(ga, 0), 1.0);
if (ISEQUALF(GAAdn(ga, 0)->_val, 1.0) == false ||
    ISEQUALF(ga->_adns->_tail->_sortVal, 1.0) == false) {
    GenAlgErr->_type = PBErTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetAdnValue failed");
    PBErCatch(GenAlgErr);
}
GenAlgFree(&ga);
ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES, 3, 3);
GASetTypeNeuraNet(ga, 1, 2, 3);
if (GAGetType(ga) != genAlgTypeNeuraNet ||
    ga->_NNdata._nbIn != 1 ||
    ga->_NNdata._nbHid != 2 ||
    ga->_NNdata._nbOut != 3) {
    GenAlgErr->_type = PBErTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASetTypeNeuraNet failed");
    PBErCatch(GenAlgErr);
}
GenAlgFree(&ga);
printf("UnitTestGenAlgGetSet OK\n");
}

void UnitTestGenAlgInit() {
    srandom(5);
    int lengthAdnF = 2;
    int lengthAdnI = 2;
    GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
        lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
    GASetBoundsAdnFloat(ga, 0, &boundsF);
    GASetBoundsAdnFloat(ga, 1, &boundsF);
    GASetBoundsAdnInt(ga, 0, &boundsI);
    GASetBoundsAdnInt(ga, 1, &boundsI);
    GAIInit(ga);
    GenAlgAdn* ent = (GenAlgAdn*)(GAAdns(ga)->_head->_data);
    if (ISEQUALF(VecGet(ent->_adnF, 0), -0.907064) == false ||

```

```

    ISEQUALF(VecGet(ent->_adnF, 1), -0.450509) == false ||
    VecGet(ent->_adnI, 0) != 2 ||
    VecGet(ent->_adnI, 1) != 10) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAINit failed");
        PBErrCatch(GenAlgErr);
    }
    GenAlgFree(&ga);
    printf("UnitTestGenAlgInit OK\n");
}

void UnitTestGenAlgPrint() {
    srand(5);
    int lengthAdnF = 2;
    int lengthAdnI = 2;
    GenAlg* ga = GenAlgCreate(3, 2, lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
    GASetBoundsAdnFloat(ga, 0, &boundsF);
    GASetBoundsAdnFloat(ga, 1, &boundsF);
    GASetBoundsAdnInt(ga, 0, &boundsI);
    GASetBoundsAdnInt(ga, 1, &boundsI);
    GAINit(ga);
    GAPrintln(ga, stdout);
    GAEliteSummaryPrintln(ga, stdout);
    GenAlgFree(&ga);
    printf("UnitTestGenAlgInit OK\n");
}

void UnitTestGenAlgGetDiversity() {
    srand(5);
    int lengthAdnF = 2;
    int lengthAdnI = 2;
    GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
        lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
    GASetBoundsAdnFloat(ga, 0, &boundsF);
    GASetBoundsAdnFloat(ga, 1, &boundsF);
    GASetBoundsAdnInt(ga, 0, &boundsI);
    GASetBoundsAdnInt(ga, 1, &boundsI);
    GASetNbElites(ga, 2);
    GASetNbEntities(ga, 3);
    GAINit(ga);
    if (ISEQUALF(GAGetDiversity(ga), 0.0) == false) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAGetDiversity failed");
        PBErrCatch(GenAlgErr);
    }
    VecCopy(GAAdn(ga, 1)->_adnF, GAAdn(ga, 0)->_adnF);
    VecCopy(GAAdn(ga, 1)->_adnI, GAAdn(ga, 0)->_adnI);
    if (ISEQUALF(GAGetDiversity(ga), 0.0) == false) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAGetDiversity failed");
        PBErrCatch(GenAlgErr);
    }
    GenAlgFree(&ga);
    printf("UnitTestGenAlgGetDiversity OK\n");
}

```

```

}

void UnitTestGenAlgStep() {
    srandom(2);
    int lengthAdnF = 2;
    int lengthAdnI = 2;
    GenAlg* ga = GenAlgCreate(3, 2, lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
    GASetBoundsAdnFloat(ga, 0, &boundsF);
    GASetBoundsAdnFloat(ga, 1, &boundsF);
    GASetBoundsAdnInt(ga, 0, &boundsI);
    GASetBoundsAdnInt(ga, 1, &boundsI);
    GAInit(ga);
    for (int i = 3; i--;)
        GASetAdnValue(ga, GAAdn(ga, i), 3.0 - (float)i);
    printf("Before Step:\n");
    GAPrintln(ga, stdout);
    GenAlgAdn* child = GAAdn(ga, 2);
    GAStep(ga);
    printf("After Step:\n");
    GAPrintln(ga, stdout);
    if (ga->_nextId != 4 || GAAdnGetId(child) != 3 ||
        GAAdnGetAge(child) != 1 ||
        ISEQUALF(GAAdnGetGeneF(child, 0), -0.156076) == false ||
        ISEQUALF(GAAdnGetGeneF(child, 1), 0.174965) == false ||
        ISEQUALF(GAAdnGetDeltaGeneF(child, 0), 0.0) == false ||
        ISEQUALF(GAAdnGetDeltaGeneF(child, 1), 0.0) == false ||
        GAAdnGetGeneI(child, 0) != 4 ||
        GAAdnGetGeneI(child, 1) != 7 ||
        GAAdn(ga, 2) != child ||
        GAAdnGetAge(GAAdn(ga, 0)) != 2 ||
        GAAdnGetAge(GAAdn(ga, 1)) != 2 ||
        GAAdnGetId(GAAdn(ga, 0)) != 0 ||
        GAAdnGetId(GAAdn(ga, 1)) != 1) {
        GenAlgErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GenAlgErr->_msg, "GAStep failed");
        PBErrCatch(GenAlgErr);
    }
    GenAlgFree(&ga);
    printf("UnitTestGenAlgStep OK\n");
}

void UnitTestGenAlgLoadSave() {
    srandom(5);
    int lengthAdnF = 2;
    int lengthAdnI = 2;
    GenAlg* ga = GenAlgCreate(3, 2, lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 1); VecSet(&boundsI, 1, 10);
    GASetBoundsAdnFloat(ga, 0, &boundsF);
    GASetBoundsAdnFloat(ga, 1, &boundsF);
    GASetBoundsAdnInt(ga, 0, &boundsI);
    GASetBoundsAdnInt(ga, 1, &boundsI);
    GAInit(ga);
    GAStep(ga);
    GSet* rank = GSetCreate();
    for (int i = 3; i--;)

```

```

    GSetAddSort(rank, GAAdn(ga, i), 3.0 - (float)i);
FILE* stream = fopen("./UnitTestGenAlgLoadSave.txt", "w");
if (GASave(ga, stream, false) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GASave failed");
    PBErrCatch(GenAlgErr);
}
fclose(stream);
stream = fopen("./UnitTestGenAlgLoadSave.txt", "r");
GenAlg* gaLoad = NULL;
if (GALoad(&gaLoad, stream) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "GALoad failed");
    PBErrCatch(GenAlgErr);
}
fclose(stream);
if (ga->_nextId != gaLoad->_nextId ||
    ga->_curEpoch != gaLoad->_curEpoch ||
    ga->_nbElites != gaLoad->_nbElites ||
    ga->_type != genAlgTypeDefault ||
    ga->_lengthAdnF != gaLoad->_lengthAdnF ||
    ga->_lengthAdnI != gaLoad->_lengthAdnI ||
    VecIsEqual(ga->_boundsF, gaLoad->_boundsF) == false ||
    VecIsEqual(ga->_boundsF + 1, gaLoad->_boundsF + 1) == false ||
    VecIsEqual(ga->_boundsI, gaLoad->_boundsI) == false ||
    VecIsEqual(ga->_boundsI + 1, gaLoad->_boundsI + 1) == false ||
    GAAdnGetId(GAAdn(ga, 0)) != GAAdnGetId(GAAdn(gaLoad, 0)) ||
    GAAdnGetId(GAAdn(ga, 1)) != GAAdnGetId(GAAdn(gaLoad, 1)) ||
    GAAdnGetId(GAAdn(ga, 2)) != GAAdnGetId(GAAdn(gaLoad, 2)) ||
    GAAdnGetAge(GAAdn(ga, 0)) != GAAdnGetAge(GAAdn(gaLoad, 0)) ||
    GAAdnGetAge(GAAdn(ga, 1)) != GAAdnGetAge(GAAdn(gaLoad, 1)) ||
    GAAdnGetAge(GAAdn(ga, 2)) != GAAdnGetAge(GAAdn(gaLoad, 2)) ||
    VecIsEqual(GAAdn(ga, 0)->_adnF,
        GAAdn(gaLoad, 0)->_adnF) == false ||
    VecIsEqual(GAAdn(ga, 0)->_deltaAdnF,
        GAAdn(gaLoad, 0)->_deltaAdnF) == false ||
    VecIsEqual(GAAdn(ga, 0)->_adnI,
        GAAdn(gaLoad, 0)->_adnI) == false ||
    VecIsEqual(GAAdn(ga, 1)->_adnF,
        GAAdn(gaLoad, 1)->_adnF) == false ||
    VecIsEqual(GAAdn(ga, 1)->_deltaAdnF,
        GAAdn(gaLoad, 1)->_deltaAdnF) == false ||
    VecIsEqual(GAAdn(ga, 1)->_adnI,
        GAAdn(gaLoad, 1)->_adnI) == false ||
    VecIsEqual(GAAdn(ga, 2)->_adnF,
        GAAdn(gaLoad, 2)->_adnF) == false ||
    VecIsEqual(GAAdn(ga, 2)->_deltaAdnF,
        GAAdn(gaLoad, 2)->_deltaAdnF) == false ||
    VecIsEqual(GAAdn(ga, 2)->_adnI,
        GAAdn(gaLoad, 2)->_adnI) == false) {
    GenAlgErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GenAlgErr->_msg, "UnitTestGenAlgLoadSave failed");
    PBErrCatch(GenAlgErr);
}
GSetFree(&rank);
GenAlgFree(&ga);
GenAlgFree(&gaLoad);
printf("UnitTestGenAlgLoadSave OK\n");
}

float ftarget(float x) {
    return -0.5 * fastpow(x, 3) + 0.314 * fastpow(x, 2) - 0.7777 * x + 0.1;
}

```

```

}

float evaluate(const VecFloat* adnF, const VecShort* adnI) {
    float delta = 0.02;
    int nb = (int)round(4.0 / delta);
    float res = 0.0;
    float x = -2.0;
    for (int i = 0; i < nb; ++i, x += delta) {
        float y = 0.0;
        for (int j = 4; j--;)
            y += VecGet(adnF, j) * fastpow(x, VecGet(adnI, j));
        res += fabs(ftarget(x) - y);
    }
    return res / (float)nb;
}

void UnitTestGenAlgTest() {
    srand(5);
    int lengthAdnF = 4;
    int lengthAdnI = lengthAdnF;
    GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
        lengthAdnF, lengthAdnI);
    VecFloat2D boundsF = VecFloatCreateStatic2D();
    VecShort2D boundsI = VecShortCreateStatic2D();
    VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
    VecSet(&boundsI, 0, 0); VecSet(&boundsI, 1, 4);
    for (int i = lengthAdnF; i--;) {
        GASetBoundsAdnFloat(ga, i, &boundsF);
        GASetBoundsAdnInt(ga, i, &boundsI);
    }
    GAINit(ga);
    //GASetDiversityThreshold(ga, 0.0);
    float best = 1.0;
    //int step = 0;
    do {
        //float ev = evaluate(GABestAdnF(ga), GABestAdnI(ga));
        //printf("%lu %f %f\n", GAGetCurEpoch(ga), ev, GAGetDiversity(ga));
        for (int iEnt = GAGetNbAdns(ga); iEnt--;)
            if (GAAdnIsNew(GAAdn(ga, iEnt)))
                GASetAdnValue(ga, GAAdn(ga, iEnt),
                    -1.0 * evaluate(GAAdnAdnF(GAAdn(ga, iEnt)),
                        GAAdnAdnI(GAAdn(ga, iEnt))));
        GAStep(ga);
        float ev = evaluate(GABestAdnF(ga), GABestAdnI(ga));
        //if (step == 10){
        //    printf("%d %f %f\n", GAGetCurEpoch(ga), ev, GAGetDiversity(ga));
        //    step = 0;
        //} else step++;
        if (best - ev > PBMMATH_EPSILON) {
            best = ev;
            printf("%lu %f ", GAGetCurEpoch(ga), best);
            VecFloatPrint(GABestAdnF(ga), stdout, 6);
            printf(" ");
            VecPrint(GABestAdnI(ga), stdout);
            printf("\n");
        }
    } while (GAGetCurEpoch(ga) < 20000 ||
        evaluate(GABestAdnF(ga), GABestAdnI(ga)) < PBMMATH_EPSILON);
    printf("target: -0.5*x^3 + 0.314*x^2 - 0.7777*x + 0.1\n");
    printf("approx: \n");
    GAAdnPrintln(GABestAdn(ga), stdout);
    printf("error: %f\n", evaluate(GABestAdnF(ga), GABestAdnI(ga)));
}

```



```

    GenAlgFree(&ga);
    printf("UnitTestGenAlgTest OK\n");
}

void UnitTestGenAlgPerf() {
    int nbRun = 500;
    unsigned long int nbMaxEpoch = 2000;
    float maxEv = 0.0;
    float bestEv = 0.0;
    float sumEv = 0.0;
    float avgEv = 0.0;
    for (int iRun = 0; iRun < nbRun; ++iRun) {
        srand(time(NULL));
        int lengthAdnF = 4;
        int lengthAdnI = lengthAdnF;
        GenAlg* ga = GenAlgCreate(GENALG_NBENTITIES, GENALG_NBELITES,
            lengthAdnF, lengthAdnI);
        VecFloat2D boundsF = VecFloatCreateStatic2D();
        VecShort2D boundsI = VecShortCreateStatic2D();
        VecSet(&boundsF, 0, -1.0); VecSet(&boundsF, 1, 1.0);
        VecSet(&boundsI, 0, 0); VecSet(&boundsI, 1, 4);
        for (int i = lengthAdnF; i--;) {
            GASetBoundsAdnFloat(ga, i, &boundsF);
            GASetBoundsAdnInt(ga, i, &boundsI);
        }
        GAInit(ga);
        float ev = 0.0;
        do {
            for (int iEnt = GAGetNbAdns(ga); iEnt--;)
                if (GAAdnIsNew(GAAdn(ga, iEnt)))
                    GASetAdnValue(ga, GAAdn(ga, iEnt),
                        -1.0 * evaluate(GAAdnAdnF(GAAdn(ga, iEnt)),
                            GAAdnAdnI(GAAdn(ga, iEnt))));
            GASTep(ga);
            ev = evaluate(GABestAdnF(ga), GABestAdnI(ga));
        } while (GAGetCurEpoch(ga) < nbMaxEpoch || ev < PBMath_EPSILON);
        sumEv += ev;
        if (iRun == 0 || bestEv > ev)
            bestEv = ev;
        if (iRun == 0 || maxEv < ev)
            maxEv = ev;
        //avgEv = sumEv / (float)iRun;
        //printf("best: %f, worst: %f, avg: %f, %lu\n", bestEv, maxEv, avgEv, ga->_nbKTEvent);
        GenAlgFree(&ga);
    }
    avgEv = sumEv / (float)nbRun;
    printf("in %d runs, %lu epochs, best: %f, worst: %f, avg: %f\n",
        nbRun, nbMaxEpoch, bestEv, maxEv, avgEv);
    printf("UnitTestGenAlgPerf OK\n");
}

void UnitTestGenAlg() {
    UnitTestGenAlgCreateFree();
    UnitTestGenAlgGetSet();
    UnitTestGenAlgInit();
    UnitTestGenAlgPrint();
    UnitTestGenAlgGetDiversity();
    UnitTestGenAlgStep();
    UnitTestGenAlgLoadSave();
    UnitTestGenAlgTest();
    UnitTestGenAlgPerf();
    printf("UnitTestGenAlg OK\n");
}

```

```

}

void UnitTestAll() {
    UnitTestGenAlgAdn();
    UnitTestGenAlg();
    printf("UnitTestAll OK\n");
}

int main() {
    UnitTestAll();
    //UnitTestGenAlgPerf();
    // Return success code
    return 0;
}

```

6 Unit tests output

```

UnitTestGenAlgAdnCreateFree OK
UnitTestGenAlgAdnGetSet OK
UnitTestGenAlgAdnInit OK
UnitTestGenAlgAdn OK
UnitTestGenAlgCreateFree OK
UnitTestGenAlgGetSet OK
UnitTestGenAlgInit OK
epoch:0
3 entities, 2 elites
#0 value:0.000000 elite id:0 age:1
  adnF:<0.788004,-0.003504>
  deltaAdnF:<0.000000,0.000000>
  adnI:<3,1>
#1 value:0.000000 elite id:1 age:1
  adnF:<-0.840711,-0.704622>
  deltaAdnF:<0.000000,0.000000>
  adnI:<5,4>
#2 value:0.000000 id:2 age:1
  adnF:<-0.907064,-0.450509>
  deltaAdnF:<0.000000,0.000000>
  adnI:<2,10>
(age,val,div) (1,0.000,0.000) (1,0.000,0.455)
UnitTestGenAlgInit OK
UnitTestGenAlgGetDiversity OK
Before Step:
epoch:0
3 entities, 2 elites
#0 value:3.000000 elite id:0 age:1
  adnF:<0.285933,0.174965>
  deltaAdnF:<0.000000,0.000000>
  adnI:<4,10>
#1 value:2.000000 elite id:1 age:1
  adnF:<-0.156076,-0.303386>
  deltaAdnF:<0.000000,0.000000>
  adnI:<2,7>
#2 value:1.000000 id:2 age:1
  adnF:<0.619353,0.401953>
  deltaAdnF:<0.000000,0.000000>
  adnI:<2,2>
After Step:
epoch:1

```

```

3 entities, 2 elites
#0 value:3.000000 elite id:0 age:2
  adnF:<0.285933,0.174965>
  deltaAdnF:<0.000000,0.000000>
  adnI:<4,10>
#1 value:2.000000 elite id:1 age:2
  adnF:<-0.156076,-0.303386>
  deltaAdnF:<0.000000,0.000000>
  adnI:<2,7>
#2 value:1.000000 id:3 age:1
  adnF:<-0.156076,0.174965>
  deltaAdnF:<0.000000,0.000000>
  adnI:<4,7>
UnitTestGenAlgStep OK
UnitTestGenAlgLoadSave OK
2 0.256155 <0.568557,-0.743738,0.349810,-0.728776> <1,1,2,3>
5 0.164266 <-0.540080,-0.789917,0.214752,0.432405> <1,3,3,2>
10 0.128932 <0.410541,-0.899703,0.349810,-0.596805> <1,1,2,3>
12 0.111252 <0.315120,-0.899703,0.349810,-0.596805> <1,1,2,3>
13 0.110277 <0.315120,-0.881148,0.349810,-0.596805> <1,1,2,3>
17 0.108536 <0.348351,-0.896048,0.349810,-0.572533> <1,1,2,3>
20 0.074050 <0.195528,-0.875461,0.341126,-0.540044> <1,1,2,3>
24 0.067420 <0.195528,-0.863918,0.349810,-0.540044> <1,1,2,3>
33 0.067350 <0.195528,-0.863918,0.349810,-0.539760> <1,1,2,3>
34 0.066606 <-0.511536,-0.834290,0.349810,0.022997> <3,1,2,3>
39 0.061147 <-0.511536,-0.799226,0.349810,0.022997> <3,1,2,3>
46 0.059587 <-0.511536,-0.815583,0.349810,0.022997> <3,1,2,3>
49 0.059188 <-0.511536,-0.799226,0.358309,0.022997> <3,1,2,3>
69 0.059030 <-0.511536,-0.803219,0.358309,0.022997> <3,1,2,3>
112 0.058988 <-0.018471,-0.503888,-0.770280,0.370470> <2,3,1,2>
116 0.058977 <-0.018471,-0.511468,-0.746625,0.370470> <2,3,1,2>
120 0.058934 <-0.018471,-0.503888,-0.769498,0.370470> <2,3,1,2>
169 0.058876 <-0.018471,-0.503888,-0.767888,0.370470> <2,3,1,2>
221 0.058276 <-0.760091,-0.503888,0.027957,0.370470> <1,3,0,2>
379 0.043868 <-0.487453,0.329138,0.091891,-0.759397> <3,2,0,1>
381 0.033849 <-0.506735,0.329138,0.091891,-0.797105> <3,2,0,1>
383 0.017690 <-0.487453,0.329138,0.091891,-0.797105> <3,2,0,1>
412 0.015545 <-0.489918,0.329138,0.084616,-0.792611> <3,2,0,1>
419 0.013435 <-0.489918,0.325125,0.093707,-0.792611> <3,2,0,1>
432 0.013191 <-0.490301,0.325125,0.093707,-0.792611> <3,2,0,1>
436 0.012435 <-0.491399,0.325125,0.084616,-0.792611> <3,2,0,1>
441 0.009605 <-0.491399,0.316610,0.093230,-0.792611> <3,2,0,1>
512 0.008978 <-0.491399,0.316610,0.099342,-0.792519> <3,2,0,1>
685 0.008914 <-0.491399,0.316610,0.099342,-0.795866> <3,2,0,1>
698 0.008669 <-0.491399,0.315271,0.099342,-0.795866> <3,2,0,1>
831 0.007160 <-0.505292,0.315271,0.099342,-0.761168> <3,2,0,1>
852 0.006604 <-0.505292,0.310593,0.099342,-0.766974> <3,2,0,1>
860 0.005412 <-0.505292,0.315271,0.099342,-0.766974> <3,2,0,1>
912 0.004970 <-0.504548,0.315271,0.099342,-0.766468> <3,2,0,1>
914 0.004855 <-0.504548,0.315271,0.099342,-0.766974> <3,2,0,1>
961 0.004743 <-0.504548,0.313669,0.099342,-0.766974> <3,2,0,1>
1187 0.001497 <0.314424,-0.774460,0.099975,-0.501049> <2,1,0,3>
1188 0.001310 <0.314424,-0.774837,0.099975,-0.501049> <2,1,0,3>
1549 0.001174 <0.314424,-0.776076,0.099975,-0.501049> <2,1,0,3>
2531 0.001162 <0.314424,-0.776008,0.099975,-0.501049> <2,1,0,3>
3233 0.000898 <0.314424,-0.776008,0.099975,-0.500637> <2,1,0,3>
3559 0.000814 <0.314424,-0.776008,0.099241,-0.500637> <2,1,0,3>
4960 0.000794 <0.314238,-0.776008,0.099241,-0.500637> <2,1,0,3>
5821 0.000782 <0.314238,-0.776008,0.100058,-0.500637> <2,1,0,3>
6877 0.000745 <0.314238,-0.776125,0.100058,-0.500637> <2,1,0,3>
7095 0.000712 <0.314238,-0.776125,0.099856,-0.500637> <2,1,0,3>
7157 0.000677 <0.314054,-0.776125,0.099856,-0.500637> <2,1,0,3>

```

```

target: -0.5*x^3 + 0.314*x^2 - 0.7777*x + 0.1
approx:
id:1167158 age:1
  adnF:<0.314021,-0.776125,0.099987,-0.500637>
  deltaAdnF:<-0.000033,0.048377,-0.012747,0.000411>
  adnI:<2,1,0,3>
error: 0.000674
UnitTestGenAlgTest OK
in 500 runs, 2000 epochs, best: 0.000285, worst: 0.007826, avg: 0.002240
UnitTestGenAlgPerf OK
UnitTestGenAlg OK
UnitTestAll OK

```

UnitTestGenAlgLoadSave.txt:

```

{
  "_type": "0",
  "_nbAdns": "3",
  "_nbElites": "2",
  "_lengthAdnF": "2",
  "_lengthAdnI": "2",
  "_curEpoch": "1",
  "_nextId": "4",
  "_boundFloat": [
    {
      "_dim": "2",
      "_val": ["-1.000000", "1.000000"]
    },
    {
      "_dim": "2",
      "_val": ["-1.000000", "1.000000"]
    }
  ],
  "_boundInt": [
    {
      "_dim": "2",
      "_val": ["1", "10"]
    },
    {
      "_dim": "2",
      "_val": ["1", "10"]
    }
  ],
  "_adns": [
    {
      "_id": "3",
      "_age": "1",
      "_elo": "0.000000",
      "_val": "1.000000",
      "_adnF": {
        "_dim": "2",
        "_val": ["0.672516", "-0.003504"]
      },
      "_deltaAdnF": {
        "_dim": "2",
        "_val": ["-0.115488", "0.000000"]
      },
      "_adnI": {
        "_dim": "2",
        "_val": ["3", "1"]
      }
    }
  ]
}

```

```

    },
    {
      "_id": "1",
      "_age": "2",
      "_elo": "0.000000",
      "_val": "2.000000",
      "_adnF": {
        "_dim": "2",
        "_val": ["-0.840711", "-0.704622"]
      },
      "_deltaAdnF": {
        "_dim": "2",
        "_val": ["0.000000", "0.000000"]
      },
      "_adnI": {
        "_dim": "2",
        "_val": ["5", "4"]
      }
    },
    {
      "_id": "0",
      "_age": "2",
      "_elo": "0.000000",
      "_val": "3.000000",
      "_adnF": {
        "_dim": "2",
        "_val": ["0.788004", "-0.003504"]
      },
      "_deltaAdnF": {
        "_dim": "2",
        "_val": ["0.000000", "0.000000"]
      },
      "_adnI": {
        "_dim": "2",
        "_val": ["3", "1"]
      }
    }
  ],
  "_bestAdn": {
    "_id": "0",
    "_age": "1",
    "_elo": "0.000000",
    "_val": "3.000000",
    "_adnF": {
      "_dim": "2",
      "_val": ["0.788004", "-0.003504"]
    },
    "_deltaAdnF": {
      "_dim": "2",
      "_val": ["0.000000", "0.000000"]
    },
    "_adnI": {
      "_dim": "2",
      "_val": ["3", "1"]
    }
  }
}

```

eval() of best genes over epoch:

