GradAutomaton

P. Baillehache

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Contents

Introduction

GradAutomaton is a C library providing structures and functions to manipulate cellular automaton based on Grad structures.

It currently implements the following cellular automaton:

- GradAutomatonWolframOriginal: Cellular automaton described page 53 of "A new kind of science" by S. Wolfram
- GradAutomatonNeuraNet: Cellular Automaton on GradSquare and GradHexa where the automaton function is a NeuraNet

It uses the `PBErr`, `Grad`, `NeuraNet`, `PBJson` libraries.

1 Definitions

2 Interface

```
// ============ GRADAUTOMATON.H ================

#ifndef GRADAUTOMATON_H
#define GRADAUTOMATON_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"
#include "grad.h"
#include "genalg.h"
#include "neuranet.h"

// -------------- GrACell

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

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

typedef struct GrACell {

  // Index of the current status of the cell
  unsigned char curStatus;

  // Pointer toward the supporting GradCell
  GradCell* gradCell;

} GrACell;

typedef struct GrACellShort {

  // Parent GrACell
  GrACell gradAutomatonCell;

  // Double buffered status of the cell
  VecShort* status[2];

} GrACellShort;

typedef struct GrACellFloat {

  // Parent GrACell
  GrACell gradAutomatonCell;

  // Double buffered status of the cell
  VecFloat* status[2];

} GrACellFloat;

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

```
// Create a new static GradAutomatonCell
GrACell GradAutomatonCellCreateStatic(
  GradCell* const gradCell);

// Create a new GrACellShort with a status vector of dimension 'dim'
// for the GradCell 'gradCell'
GrACellShort* GrACellCreateShort(
       const long dim,
  GradCell* const gradCell);

// Create a new GrACellFloat with a status vector of dimension 'dim'
// for the GradCell 'gradCell'
GrACellFloat* GrACellCreateFloat(
       const long dim,
  GradCell* const gradCell);

// Free the memory used by the GrACellShort 'that'
void _GrACellShortFree(GrACellShort** that);

// Free the memory used by the GrACellFloat 'that'
void _GrACellFloatFree(GrACellFloat** that);

// Switch the current status of the GrACell 'that'
#if BUILDMODE != 0
static inline
#endif
void _GrACellSwitchStatus(GrACell* const that);

// Return the current status of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
VecShort* _GrACellShortCurStatus(const GrACellShort* const that);

// Return the current status of the GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
VecFloat* _GrACellFloatCurStatus(const GrACellFloat* const that);

// Return the previous status of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
VecShort* _GrACellShortPrevStatus(const GrACellShort* const that);

// Return the previous status of the GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
VecFloat* _GrACellFloatPrevStatus(const GrACellFloat* const that);

// Return the 'iVal'-th value of the previous status of the
// GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
short _GrACellShortGetPrevStatus(
  const GrACellShort* const that,
        const unsigned long iVal);
```

```
// Return the 'iVal'-th value of the previous status of the
// GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
float _GrACellFloatGetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal);

// Set the 'iVal'-th value of the previous status of the
// GrACellShort 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellShortSetPrevStatus(
  const GrACellShort* const that,
        const unsigned long iVal,
                const short val);

// Set the 'iVal'-th value of the previous status of the
// GrACellFloat 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellFloatSetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal,
                const float val);

// Return the 'iVal'-th value of the current status of the
// GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
short _GrACellShortGetCurStatus(
  const GrACellShort* const that,
        const unsigned long iVal);

// Return the 'iVal'-th value of the current status of the
// GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
float _GrACellFloatGetCurStatus(
  const GrACellFloat* const that,
        const unsigned long iVal);

// Set the 'iVal'-th value of the current status of the
// GrACellShort 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellShortSetCurStatus(
  const GrACellShort* const that,
        const unsigned long iVal,
                const short val);

// Set the 'iVal'-th value of the current status of the
// GrACellFloat 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
```

```
void _GrACellFloatSetCurStatus(
  const GrACellFloat* const that,
        const unsigned long iVal,
                const float val);

// Return the GradCell of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
GradCell* _GrACellShortGradCell(const GrACellShort* const that);

// Return the GradCell of the GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
GradCell* _GrACellFloatGradCell(const GrACellFloat* const that);

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

#define GrACellFree(G) _Generic(G, \
  GrACellShort**: _GrACellShortFree, \
  GrACellFloat**: _GrACellFloatFree, \
  default: PBErrInvalidPolymorphism)(G)

#define GrACellSwitchStatus(G) _Generic(G, \
  GrACell*: _GrACellSwitchStatus, \
  GrACellShort*: _GrACellSwitchStatus, \
  GrACellFloat*: _GrACellSwitchStatus, \
  default: PBErrInvalidPolymorphism)((GrACell*)(G))

#define GrACellCurStatus(G) _Generic(G, \
  GrACellShort*: _GrACellShortCurStatus, \
  const GrACellShort*: _GrACellShortCurStatus, \
  GrACellFloat*: _GrACellFloatCurStatus, \
  const GrACellFloat*: _GrACellFloatCurStatus, \
  default: PBErrInvalidPolymorphism)(G)

#define GrACellPrevStatus(G) _Generic(G, \
  GrACellShort*: _GrACellShortPrevStatus, \
  const GrACellShort*: _GrACellShortPrevStatus, \
  GrACellFloat*: _GrACellFloatPrevStatus, \
  const GrACellFloat*: _GrACellFloatPrevStatus, \
  default: PBErrInvalidPolymorphism)(G)

#define GrACellGetCurStatus(G, I) _Generic(G, \
  GrACellShort*: _GrACellShortGetCurStatus, \
  const GrACellShort*: _GrACellShortGetCurStatus, \
  GrACellFloat*: _GrACellFloatGetCurStatus, \
  const GrACellFloat*: _GrACellFloatGetCurStatus, \
  default: PBErrInvalidPolymorphism)(G, I)

#define GrACellGetPrevStatus(G, I) _Generic(G, \
  GrACellShort*: _GrACellShortGetPrevStatus, \
  const GrACellShort*: _GrACellShortGetPrevStatus, \
  GrACellFloat*: _GrACellFloatGetPrevStatus, \
  const GrACellFloat*: _GrACellFloatGetPrevStatus, \
  default: PBErrInvalidPolymorphism)(G, I)

#define GrACellSetCurStatus(G, I, V) _Generic(G, \
  GrACellShort*: _GrACellShortSetCurStatus, \
  GrACellFloat*: _GrACellFloatSetCurStatus, \
  default: PBErrInvalidPolymorphism)(G, I, V)
```

```
#define GrACellSetPrevStatus(G, I, V) _Generic(G, \
  GrACellShort*: _GrACellShortSetPrevStatus, \
  GrACellFloat*: _GrACellFloatSetPrevStatus, \
  default: PBErrInvalidPolymorphism)(G, I, V)

#define GrACellGradCell(G) _Generic(G, \
  GrACellShort*: _GrACellShortGradCell, \
  const GrACellShort*: _GrACellShortGradCell, \
  GrACellFloat*: _GrACellFloatGradCell, \
  const GrACellFloat*: _GrACellFloatGradCell, \
  default: PBErrInvalidPolymorphism)(G)

// -------------- GrAFun

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

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

typedef enum GrAFunType {

  GrAFunTypeDummy,
  GrAFunTypeWolframOriginal,
  GrAFunTypeNeuraNet

} GrAFunType;

typedef struct GrAFun {

  // Type of GrAFun
  GrAFunType type;

} GrAFun;

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

// Create a static GrAFun with type 'type'
GrAFun GrAFunCreateStatic(const GrAFunType type);

// Free the memory used by the GrAFun 'that'
void _GrAFunFreeStatic(GrAFun* that);

// Return the type of the GrAFun 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunType _GrAFunGetType(const GrAFun* const that);

// -------------- GrAFunDummy

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

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

typedef struct GrAFunDummy {

  // GrAFun
  GrAFun grAFun;

} GrAFunDummy;

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

```
// Create a new GrAFunDummy
GrAFunDummy* GrAFunCreateDummy(void);

// Free the memory used by the GrAFunDummy 'that'
void _GrAFunDummyFree(GrAFunDummy** that);

// -------------- GrAFunWolframOriginal

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

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

typedef struct GrAFunWolframOriginal {

  // GrAFun
  GrAFun grAFun;

  // Rule, cf "A new kind of science" p.53
  unsigned char rule;

} GrAFunWolframOriginal;

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

// Create a new GrAFunWolframOriginal
GrAFunWolframOriginal* GrAFunCreateWolframOriginal(
  const unsigned char rule);

// Free the memory used by the GrAFunWolframOriginal 'that'
void _GrAFunWolframOriginalFree(GrAFunWolframOriginal** that);

// Return the rule of the GrAFunWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
unsigned char GrAFunWolframOriginalGetRule(
  GrAFunWolframOriginal* const that);

// Apply the step function for the GrAFunWolframOriginal 'that'
// to the GrACellShort 'cell' in the GradSquare 'grad'
void _GrAFunWolframOriginalApply(
  GrAFunWolframOriginal* const that,
             GradSquare* const grad,
           GrACellShort* const cell);

// -------------- GrAFunNeuraNet

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

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

typedef struct GrAFunNeuraNet {

  // GrAFun
  GrAFun grAFun;

  // NeuraNet applied to the cells
  NeuraNet* nn;

} GrAFunNeuraNet;
```

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

// Create a new GrAFunNeuraNet
GrAFunNeuraNet* GrAFunCreateNeuraNet(
             const int nbIn,
             const int nbOut,
  const VecLong* const hiddenLayers);

// Free the memory used by the GrAFunNeuraNet 'that'
void _GrAFunNeuraNetFree(GrAFunNeuraNet** that);

// Return the NeuraNet of the GrAFunNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
NeuraNet* GrAFunNeuraNetNN(
  GrAFunNeuraNet* const that);

// Apply the step function for the GrAFunNeuraNet 'that'
// to the GrACellShort 'cell' in the GradSquare 'grad'
void _GrAFunNeuraNetApply(
  GrAFunNeuraNet* const that,
           Grad* const grad,
    GrACellFloat* const cell);

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

#define GrAFunFree(G) _Generic(G, \
  GrAFun*: _GrAFunFreeStatic, \
  GrAFunDummy**: _GrAFunDummyFree, \
  GrAFunWolframOriginal**: _GrAFunWolframOriginalFree, \
  GrAFunNeuraNet**: _GrAFunNeuraNetFree, \
  default: PBErrInvalidPolymorphism)(G)

#define GrAFunGetType(G) _Generic(G, \
  GrAFun*: _GrAFunGetType, \
  const GrAFun*: _GrAFunGetType, \
  GrAFunDummy*: _GrAFunGetType, \
  const GrAFunDummy*: _GrAFunGetType, \
  GrAFunWolframOriginal*: _GrAFunGetType, \
  const GrAFunWolframOriginal*: _GrAFunGetType, \
  GrAFunNeuraNet*: _GrAFunGetType, \
  const GrAFunNeuraNet*: _GrAFunGetType, \
  default: PBErrInvalidPolymorphism)((const GrAFun*)(G))

#define GrAFunApply(F, G, C) _Generic(F, \
  GrAFunWolframOriginal*: _GrAFunWolframOriginalApply, \
  GrAFunNeuraNet*: _GrAFunNeuraNetApply, \
  default: PBErrInvalidPolymorphism)(F, G, C)

// -------------- GradAutomaton

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

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

typedef enum GradAutomatonType {

  GradAutomatonTypeDummy,
  GradAutomatonTypeWolframOriginal,
  GradAutomatonTypeNeuraNet
```

```
} GradAutomatonType;

typedef struct GradAutomaton {

  // Type of the GradAutomaton
  GradAutomatonType type;

  // Dimension of the status vector of each cell
  long dimStatus;

  // Grad
  Grad* grad;

  // GrAFun
  GrAFun* fun;

  // Flag to memorize if the GradAutomaton is stable
  // i.e., current step is same as previous step after GradAutomatonStep
  bool isStable;

} GradAutomaton;

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

// Create a new static GradAutomaton
GradAutomaton GradAutomatonCreateStatic(
  const GradAutomatonType type,
              Grad* const grad,
            GrAFun* const fun,
               const long dimStatus);

// Return the Grad of the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
Grad* _GradAutomatonGrad(const GradAutomaton* const that);

// Return the GrACell at position 'pos' for the
// GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
GrACell* _GradAutomatonCellPos(
     GradAutomaton* const that,
  const VecShort2D* const pos);

// Return the GrACell at index 'iCell' for the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
GrACell* _GradAutomatonCellIndex(
  GradAutomaton* const that,
            const long iCell);

// Switch the status of all the cells of the GradAutomaton 'that'
void _GradAutomatonSwitchAllStatus(GradAutomaton* const that);

// Return the dimension of the status of the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
long _GradAutomatonGetDimStatus(const GradAutomaton* const that);
```

```
// Return the flag isStable of the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
bool _GradAutomatonIsStable(const GradAutomaton* const that);

// -------------- GradAutomatonDummy

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

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

// GradSquare (2x2, no diag), GraFunDummy, GrACellShort dimension 1
typedef struct GradAutomatonDummy {

  // Parent GradAutomaton
  GradAutomaton gradAutomaton;

} GradAutomatonDummy;

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

// Create a new GradAutomatonDummy
GradAutomatonDummy* GradAutomatonCreateDummy();

// Free the memory used by the GradAutomatonDummy 'that'
void GradAutomatonDummyFree(GradAutomatonDummy** that);

// Step the GradAutomatonDummy
void _GradAutomatonDummyStep(GradAutomatonDummy* const that);

// Return the Grad of the GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GradSquare* _GradAutomatonDummyGrad(
  const GradAutomatonDummy* const that);

// Return the GrAFun of the GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunDummy* _GradAutomatonDummyFun(
  const GradAutomatonDummy* const that);

// Return the GrACellShort at position 'pos' for the
// GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonDummyCellPos(
  GradAutomatonDummy* const that,
    const VecShort2D* const pos);

// Return the GrACellShort at index 'iCell' for the GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonDummyCellIndex(
  GradAutomatonDummy* const that,
                const long iCell);
```

```
// -------------- GradAutomatonWorlframOriginal

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

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

// GradSquare (Nx1, no diag), GraFunWolframOriginal, GrACellShort dimension 1
typedef struct GradAutomatonWolframOriginal {

  // Parent GradAutomaton
  GradAutomaton gradAutomaton;

} GradAutomatonWolframOriginal;

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

// Create a new GradAutomatonWolframOriginal
GradAutomatonWolframOriginal* GradAutomatonCreateWolframOriginal(
  const unsigned char rule,
          const long size);

// Free the memory used by the GradAutomatonWolframOriginal 'that'
void GradAutomatonWolframOriginalFree(
  GradAutomatonWolframOriginal** that);

// Step the GradAutomatonWolframOriginal
void _GradAutomatonWolframOriginalStep(
  GradAutomatonWolframOriginal* const that);

// JSON encoding of GradAutomatonWolframOriginal 'that'
JSONNode* _GradAutomatonWolframOriginalEncodeAsJSON(
  const GradAutomatonWolframOriginal* const that);

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

// Return the Grad of the GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GradSquare* _GradAutomatonWolframOriginalGrad(
  const GradAutomatonWolframOriginal* const that);

// Return the GrAFun of the GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunWolframOriginal* _GradAutomatonWolframOriginalFun(
  const GradAutomatonWolframOriginal* const that);

// Return the GrACellShort at position 'pos' for the
// GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellPos(
  GradAutomatonWolframOriginal* const that,
             const VecShort2D* const pos);
```

```
// Return the GrACellShort at index 'iCell' for the
// GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellIndex(
  GradAutomatonWolframOriginal* const that,
                            const long iCell);

// Print the GradAutomatonWolframOriginal 'that' on the FILE 'stream'
void _GradAutomatonWolframOriginalPrintln(
  GradAutomatonWolframOriginal* const that,
                                FILE* stream);

// Save the GradAutomatonWolframOriginal 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true if the GradAutomatonWolframOriginal could be saved,
// false else
bool _GradAutomatonWolframOriginalSave(
  const GradAutomatonWolframOriginal* const that,
                                FILE* const stream,
                                 const bool compact);

// Load the GradAutomatonWolfraOriginal 'that' from the stream 'stream'
// If 'that' is not null the memory is first freed
// Return true if the GradAutomatonWolframOriginal could be loaded,
// false else
bool _GradAutomatonWolframOriginalLoad(
  GradAutomatonWolframOriginal** that,
                    FILE* const stream);

// -------------- GradAutomatonNeuraNet

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

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

// GradSquare/GradHexa, GraFunNeuraNet, GrACellFloat
typedef struct GradAutomatonNeuraNet {

  // Parent GradAutomaton
  GradAutomaton gradAutomaton;

  // Number of hidden layers
  long nbHiddenLayers;

} GradAutomatonNeuraNet;

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

// Create a new GradAutomatonNeuraNet with a GradSquare
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetSquare(
               const long dimStatus,
  const VecShort2D* const dimGrad,
               const bool diagLink,
               const long nbHiddenLayers);

// Create a new GradAutomatonNeuraNet with a GradHexa
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetHexa(
               const long dimStatus,
  const VecShort2D* const dimGrad,
```

```
       const GradHexaType gradType,
              const long nbHiddenLayers);

// Free the memory used by the GradAutomatonNeuraNet 'that'
void GradAutomatonNeuraNetFree(
  GradAutomatonNeuraNet** that);

// Step the GradAutomatonNeuraNet
void _GradAutomatonNeuraNetStep(GradAutomatonNeuraNet* const that);

// Return the Grad of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
Grad* _GradAutomatonNeuraNetGrad(
  const GradAutomatonNeuraNet* const that);

// Return the type of Grad of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GradType GradAutomatonNeuraNetGetGradType(
  GradAutomatonNeuraNet* const that);

// Return the GrAFun of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunNeuraNet* _GradAutomatonNeuraNetFun(
  const GradAutomatonNeuraNet* const that);

// Return the GrACellFloat at position 'pos' for the
// GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellFloat* _GradAutomatonNeuraNetCellPos(
  GradAutomatonNeuraNet* const that,
       const VecShort2D* const pos);

// Return the GrACellFloat at index 'iCell' for the
// GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellFloat* _GradAutomatonNeuraNetCellIndex(
  GradAutomatonNeuraNet* const that,
                    const long iCell);

// JSON encoding of GradAutomatonNeuraNet 'that'
JSONNode* _GradAutomatonNeuraNetEncodeAsJSON(
  const GradAutomatonNeuraNet* const that);

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

// Save the GradAutomatonNeuraNet 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true if the GradAutomatonNeuraNet could be saved,
```

```
// false else
bool _GradAutomatonNeuraNetSave(
  const GradAutomatonNeuraNet* const that,
                         FILE* const stream,
                          const bool compact);

// Load the GradAutomatonWolfraOriginal 'that' from the stream 'stream'
// If 'that' is not null the memory is first freed
// Return true if the GradAutomatonNeuraNet could be loaded,
// false else
bool _GradAutomatonNeuraNetLoad(
  GradAutomatonNeuraNet** that,
              FILE* const stream);

// Return the number of hidden layers of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
long GradAutomatonNeuraNetGetNbHiddenLayers(
  const GradAutomatonNeuraNet* const that);

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

#define GradAutomatonSwitchAllStatus(G) _Generic(G, \
  GradAutomaton* : _GradAutomatonSwitchAllStatus, \
  GradAutomatonDummy* : _GradAutomatonSwitchAllStatus, \
  GradAutomatonWolframOriginal* : _GradAutomatonSwitchAllStatus, \
  GradAutomatonNeuraNet* : _GradAutomatonSwitchAllStatus, \
  default: PBErrInvalidPolymorphism)((GradAutomaton*)(G))

#define GradAutomatonStep(G) _Generic(G, \
  GradAutomatonDummy* : _GradAutomatonDummyStep, \
  GradAutomatonWolframOriginal* : _GradAutomatonWolframOriginalStep, \
  GradAutomatonNeuraNet* : _GradAutomatonNeuraNetStep, \
  default: PBErrInvalidPolymorphism)(G)

#define GradAutomatonGrad(G) _Generic(G, \
  GradAutomaton* : _GradAutomatonGrad, \
  const GradAutomaton* : _GradAutomatonGrad, \
  GradAutomatonDummy* : _GradAutomatonDummyGrad, \
  const GradAutomatonDummy* : _GradAutomatonDummyGrad, \
  GradAutomatonWolframOriginal* : _GradAutomatonWolframOriginalGrad, \
  const GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalGrad, \
  GradAutomatonNeuraNet* : _GradAutomatonNeuraNetGrad, \
  const GradAutomatonNeuraNet* : _GradAutomatonNeuraNetGrad, \
  default: PBErrInvalidPolymorphism)(G)

#define GradAutomatonFun(G) _Generic(G, \
  GradAutomatonDummy* : _GradAutomatonDummyFun, \
  const GradAutomatonDummy* : _GradAutomatonDummyFun, \
  GradAutomatonWolframOriginal* : _GradAutomatonWolframOriginalFun, \
  const GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalFun, \
  GradAutomatonNeuraNet* : _GradAutomatonNeuraNetFun, \
  const GradAutomatonNeuraNet* : _GradAutomatonNeuraNetFun, \
  default: PBErrInvalidPolymorphism)(G)

#define GradAutomatonCell(G, P) _Generic(G, \
  GradAutomaton* : _Generic(P, \
    VecShort2D*: _GradAutomatonCellPos, \
    const VecShort2D*: _GradAutomatonCellPos, \
```

```
    long: _GradAutomatonCellIndex, \
    const long: _GradAutomatonCellIndex, \
    default: PBErrInvalidPolymorphism), \
  GradAutomatonDummy* : _Generic(P, \
    VecShort2D*: _GradAutomatonDummyCellPos, \
    const VecShort2D*: _GradAutomatonDummyCellPos, \
    long: _GradAutomatonDummyCellIndex, \
    const long: _GradAutomatonDummyCellIndex, \
    default: PBErrInvalidPolymorphism), \
  GradAutomatonWolframOriginal* : _Generic(P, \
    VecShort2D*: _GradAutomatonWolframOriginalCellPos, \
    const VecShort2D*: _GradAutomatonWolframOriginalCellPos, \
    long: _GradAutomatonWolframOriginalCellIndex, \
    const long: _GradAutomatonWolframOriginalCellIndex, \
    default: PBErrInvalidPolymorphism), \
  GradAutomatonNeuraNet* : _Generic(P, \
    VecShort2D*: _GradAutomatonNeuraNetCellPos, \
    const VecShort2D*: _GradAutomatonNeuraNetCellPos, \
    long: _GradAutomatonNeuraNetCellIndex, \
    const long: _GradAutomatonNeuraNetCellIndex, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(G, P)

#define GradAutomatonPrintln(G, S) _Generic(G, \
  GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalPrintln, \
  const GradAutomatonWolframOriginal* :\
    _GradAutomatonWolframOriginalPrintln, \
  default: PBErrInvalidPolymorphism)(G, S)

#define GradAutomatonEncodeAsJSON(G) _Generic(G, \
  GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalEncodeAsJSON, \
  const GradAutomatonWolframOriginal* :\
    _GradAutomatonWolframOriginalEncodeAsJSON, \
  GradAutomatonNeuraNet* : \
    _GradAutomatonNeuraNetEncodeAsJSON, \
  const GradAutomatonNeuraNet* :\
    _GradAutomatonNeuraNetEncodeAsJSON, \
  default: PBErrInvalidPolymorphism)(G)

#define GradAutomatonDecodeAsJSON(G, J) _Generic(G, \
  GradAutomatonWolframOriginal** : \
    _GradAutomatonWolframOriginalDecodeAsJSON, \
  GradAutomatonNeuraNet** : \
    _GradAutomatonNeuraNetDecodeAsJSON, \
  default: PBErrInvalidPolymorphism)(G, J)

#define GradAutomatonSave(G, S, C) _Generic(G, \
  GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalSave, \
  const GradAutomatonWolframOriginal* : \
    _GradAutomatonWolframOriginalSave, \
  GradAutomatonNeuraNet* : \
    _GradAutomatonNeuraNetSave, \
  const GradAutomatonNeuraNet* :\
    _GradAutomatonNeuraNetSave, \
  default: PBErrInvalidPolymorphism)(G, S, C)

#define GradAutomatonLoad(G, S) _Generic(G, \
  GradAutomatonWolframOriginal** : _GradAutomatonWolframOriginalLoad, \
  GradAutomatonNeuraNet** : _GradAutomatonNeuraNetLoad, \
```

```
  default: PBErrInvalidPolymorphism)(G, S)

#define GradAutomatonGetDimStatus(G) _Generic(G, \
  GradAutomaton* : _GradAutomatonGetDimStatus, \
  const GradAutomaton* : _GradAutomatonGetDimStatus, \
  GradAutomatonWolframOriginal* : _GradAutomatonGetDimStatus, \
  const GradAutomatonWolframOriginal* : _GradAutomatonGetDimStatus, \
  GradAutomatonNeuraNet* : _GradAutomatonGetDimStatus, \
  const GradAutomatonNeuraNet* : _GradAutomatonGetDimStatus, \
  default: PBErrInvalidPolymorphism)(((const GradAutomaton*)(G)))

#define GradAutomatonIsStable(G) _Generic(G, \
  GradAutomaton* : _GradAutomatonIsStable, \
  const GradAutomaton* : _GradAutomatonIsStable, \
  GradAutomatonDummy* : _GradAutomatonIsStable, \
  const GradAutomatonDummy* : _GradAutomatonIsStable, \
  GradAutomatonWolframOriginal* : _GradAutomatonIsStable, \
  const GradAutomatonWolframOriginal* : _GradAutomatonIsStable, \
  GradAutomatonNeuraNet* : _GradAutomatonIsStable, \
  const GradAutomatonNeuraNet* : _GradAutomatonIsStable, \
  default: PBErrInvalidPolymorphism)(((const GradAutomaton*)(G)))

// ================ static inliner ====================

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

#endif
```

3 Code

3.1 gradautomaton.c

```
// ============ GRADAUTOMATON.C ================

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

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

// -------------- GrACell

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

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

// Create a new static GrACell
GrACell GradAutomatonCellCreateStatic(
  GradCell* const gradCell) {

  // Create the new GradAutomatonCell
  GrACell cell;

  // Set the properties
  cell.curStatus = 0;
```

```
  cell.gradCell = gradCell;

  // Return the new GradAutomatonCell
  return cell;

}

// Create a new GrACellShort with a status vector of dimension 'dim'
// for the GradCell 'gradCell'
GrACellShort* GrACellCreateShort(
       const long dim,
  GradCell* const gradCell) {

  // Allocate memory
  GrACellShort* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GrACellShort));

  // Initialise properties
  that->status[0] = VecShortCreate(dim);
  that->status[1] = VecShortCreate(dim);
  that->gradAutomatonCell = GradAutomatonCellCreateStatic(gradCell);

  // Return the new GrACellShort
  return that;

}

// Create a new GrACellFloat with a status vector of dimension 'dim'
// for the GradCell 'gradCell'
GrACellFloat* GrACellCreateFloat(
       const long dim,
  GradCell* const gradCell) {

  // Allocate memory
  GrACellFloat* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GrACellFloat));

  // Initialise properties
  that->status[0] = VecFloatCreate(dim);
  that->status[1] = VecFloatCreate(dim);
  that->gradAutomatonCell = GradAutomatonCellCreateStatic(gradCell);

  // Return the new GrACellFloat
  return that;

}

// Free the memory used by the GrACellShort 'that'
void _GrACellShortFree(GrACellShort** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }
```

```
  // Free memory
  VecFree(&((*that)->status[0]));
  VecFree(&((*that)->status[1]));
  free(*that);
  *that = NULL;

}

// Free the memory used by the GrACellFloat 'that'
void _GrACellFloatFree(GrACellFloat** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free memory
  VecFree(&((*that)->status[0]));
  VecFree(&((*that)->status[1]));
  free(*that);
  *that = NULL;

}

// -------------- GrAFun

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

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

// Create a static GrAFun with type 'type'
GrAFun GrAFunCreateStatic(const GrAFunType type) {

  // Declare the new GrAFun
  GrAFun that;

  // Set properties
  that.type = type;

  // Return the new GrAFun
  return that;

}

// Free the memory used by the GrAFun 'that'
void _GrAFunFreeStatic(GrAFun* that) {

  // If that is null
  if (that == NULL) {

    // Do nothing
    return;

  }

}

// -------------- GrAFunDummy
```

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

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

// Create a new GrAFunDummy
GrAFunDummy* GrAFunCreateDummy(void) {

  // Declare the new GrAFun
  GrAFunDummy* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GrAFunDummy));

  // Set properties
  that->grAFun = GrAFunCreateStatic(GrAFunTypeDummy);

  // Return the new GrAFun
  return that;

}

// Free the memory used by the GrAFunDummy 'that'
void _GrAFunDummyFree(GrAFunDummy** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free memory
  _GrAFunFreeStatic((GrAFun*)(*that));
  free(*that);
  *that = NULL;

}

// -------------- GrAFunWolframOriginal

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

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

// Create a new GrAFunWolframOriginal
GrAFunWolframOriginal* GrAFunCreateWolframOriginal(
  const unsigned char rule) {

  // Declare the new GrAFun
  GrAFunWolframOriginal* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GrAFunWolframOriginal));

  // Set properties
  that->grAFun = GrAFunCreateStatic(GrAFunTypeWolframOriginal);
  that->rule = rule;

  // Return the new GrAFun
  return that;
```

```
}

// Free the memory used by the GrAFunWolframOriginal 'that'
void _GrAFunWolframOriginalFree(GrAFunWolframOriginal** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free memory
  _GrAFunFreeStatic((GrAFun*)(*that));
  free(*that);
  *that = NULL;

}

// Apply the step function for the GrAFunWolframOriginal 'that'
// to the GrACellShort 'cell' in the GradSquare 'grad'
void _GrAFunWolframOriginalApply(
  GrAFunWolframOriginal* const that,
             GradSquare* const grad,
           GrACellShort* const cell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (grad == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'grad' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (cell == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'cell' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Declare a variable to memorize the current status of the
  // cell and its neighbour
```

```
short status[3] = {0, 0, 0};

// Get the current status of the left cell
long leftLink =
  GradCellGetLink(
    GrACellGradCell(cell),
    GradSquareDirW);
if (leftLink != -1) {

  GradCell* leftNeighbour =
    GradCellNeighbour(
      grad,
      GrACellGradCell(cell),
      GradSquareDirW);
  GrACellShort* leftCell =
    (GrACellShort*)GradCellData(leftNeighbour);
  status[0] =
    VecGet(
      GrACellCurStatus(leftCell),
      0);

}

// Get the current status of the cell
status[1] =
  VecGet(
    GrACellCurStatus(cell),
    0);

// Get the current status of the right cell
long rightLink =
  GradCellGetLink(
    GrACellGradCell(cell),
    GradSquareDirE);
if (rightLink != -1) {

  GradCell* rightNeighbour =
    GradCellNeighbour(
      grad,
      GrACellGradCell(cell),
      GradSquareDirE);
  GrACellShort* rightCell =
    (GrACellShort*)GradCellData(rightNeighbour);
  status[2] =
    VecGet(
      GrACellCurStatus(rightCell),
      0);

}

// Get the corresponding mask in the rule
unsigned char mask =
  powi(
    2,
    ((status[0] * 2) + status[1]) * 2 + status[2]);

// Get the new status of the cell
short newStatus = 0;
if (GrAFunWolframOriginalGetRule(that) & mask) {

  newStatus = 1;
```

```
  }

  // Update the previous status with the new status
  // (it will be switch later)
  GrACellSetPrevStatus(
    cell,
    0,
    newStatus);

}

// -------------- GrAFunNeuraNet

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

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

// Create a new GrAFunNeuraNet
GrAFunNeuraNet* GrAFunCreateNeuraNet(
             const int nbIn,
             const int nbOut,
  const VecLong* const hiddenLayers) {

  // Declare the new GrAFun
  GrAFunNeuraNet* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GrAFunNeuraNet));

  // Set properties
  that->grAFun = GrAFunCreateStatic(GrAFunTypeNeuraNet);
  that->nn =
    NeuraNetCreateFullyConnected(
      nbIn,
      nbOut,
      hiddenLayers);

  // Return the new GrAFunNeuraNet
  return that;

}

// Free the memory used by the GrAFunNeuraNet 'that'
void _GrAFunNeuraNetFree(GrAFunNeuraNet** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free memory
  NeuraNetFree(&((*that)->nn));
  _GrAFunFreeStatic((GrAFun*)(*that));
  free(*that);
  *that = NULL;

}

// Apply the step function for the GrAFunNeuraNet 'that'
```

```
// to the GrACellShort 'cell' in the GradSquare 'grad'
void _GrAFunNeuraNetApply(
  GrAFunNeuraNet* const that,
            Grad* const grad,
    GrACellFloat* const cell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (grad == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'grad' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (cell == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'cell' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the number of links of the cell
  int nbLinks = GradCellGetNbLink(GrACellGradCell(cell));

  // Get the dimension of the input vector for the NeuraNet
  long dimInput = (nbLinks + 1) * VecGetDim(GrACellCurStatus(cell));

  // Declare a variable to memorize the input of the NeuraNet
  VecFloat* input = VecFloatCreate(dimInput);

  // Declare a variable to memorize the output of the NeuraNet
  VecFloat* output = VecFloatCreate(VecGetDim(GrACellCurStatus(cell)));

  // Set the current status of the cell in the input vector
  for (
    long iDim = VecGetDim(output);
    iDim--;) {

    float val =
      GrACellGetCurStatus(
        cell,
        iDim);

    VecSet(
```

```
    input,
    iDim,
    val);

}

// Loop on the links toward neighbour cells
for (
  long iLink = nbLinks;
  iLink--;) {

  // Get the link
  long link =
    GradCellGetLink(
      GrACellGradCell(cell),
      iLink);

  // If the link is active
  if (link != -1) {

    // Get the neighbour cell and its status
    GradCell* neighbour =
      GradCellNeighbour(
        grad,
        GrACellGradCell(cell),
        iLink);
    GrACellFloat* neighbourCell =
      (GrACellFloat*)GradCellData(neighbour);

    // Set the current status of the neighbour cell in the
    // input vector
    for (
      long iDim = VecGetDim(output);
      iDim--;) {

      float val =
        GrACellGetCurStatus(
          neighbourCell,
          iDim);

      VecSet(
        input,
        (link + 1) * VecGetDim(output) + iDim,
        val);

    }

  }

}

// Apply the NeuraNet
NNEval(
  GrAFunNeuraNetNN(that),
  input,
  output);

// Update the previous status with the output of the NeuraNet
// (it will be switch later)
for (
  long iDim = VecGetDim(output);
  iDim--;) {
```

```
    float val =
      VecGet(
        output,
        iDim);

    GrACellSetPrevStatus(
      cell,
      iDim,
      val);

  }

  // Free memory
  VecFree(&input);
  VecFree(&output);

}

// ------------- GradAutomaton

// Create a new static GradAutomaton
GradAutomaton GradAutomatonCreateStatic(
  const GradAutomatonType type,
              Grad* const grad,
            GrAFun* const fun,
               const long dimStatus) {

#if BUILDMODE == 0
  if (grad == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'grad' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (fun == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'fun' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Declare the new GradAutomaton
  GradAutomaton that;

  // Set the properties
  that.type = type;
  that.grad = grad;
  that.fun = fun;
  that.dimStatus = dimStatus;
  that.isStable = false;

  // Return the new GradAutomaton
```

```
  return that;

}

// Switch the status of all the cells of the GradAutomaton 'that'
void _GradAutomatonSwitchAllStatus(GradAutomaton* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the number of cells in the grad
  long nbCell = GradGetArea(GradAutomatonGrad(that));

  // Loop on the cell
  for (
    long iCell = nbCell;
    iCell--;) {

    // Get the cell
    GrACell* cell =
      GradAutomatonCell(
        that,
        iCell);

    // Switch the status of the cell
    GrACellSwitchStatus(cell);

  }

}

// ------------- GradAutomatonDummy

// Create a new GradAutomatonDummy
GradAutomatonDummy* GradAutomatonCreateDummy() {

  // Allocate memory for the new GradAutomatonDummy
  GradAutomatonDummy* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GradAutomatonDummy));

  // Create the associated Grad and GrAFun
  bool diagLink = false;
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(
    &dim,
    0,
    2);
  VecSet(
    &dim,
    1,
```

```
    2);
  Grad* grad =
    (Grad*)GradSquareCreate(
      &dim,
      diagLink);
  GrAFun* fun = (GrAFun*)GrAFunCreateDummy();

  // Initialize the properties
  long dimStatus = 1;
  that->gradAutomaton =
    GradAutomatonCreateStatic(
      GradAutomatonTypeDummy,
      grad,
      fun,
      dimStatus);

  // Add a GrACell to each cell of the Grad
  VecShort2D pos = VecShortCreateStatic2D();
  bool flag = true;
  do {

    GradCell* cell =
      GradCellAt(
        grad,
        &pos);

    GrACellShort* cellStatus =
      GrACellCreateShort(
        dimStatus,
        cell);

    GradCellSetData(
      cell,
      cellStatus);

    flag =
      VecStep(
        &pos,
        &dim);

  } while(flag);

  // Return the new GradAutomatonDummy
  return that;

}

// Free the memory used by the GradAutomatonDummy 'that'
void GradAutomatonDummyFree(GradAutomatonDummy** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free the GrACell attached to the cells of the Grad
  VecShort2D pos = VecShortCreateStatic2D();
  bool flag = true;
  do {
```

```
    GradCell* cell =
      GradCellAt(
        GradAutomatonGrad(*that),
        &pos);

    GrACellShort* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

    flag =
      VecStep(
        &pos,
        GradDim(GradAutomatonGrad(*that)));

  } while(flag);

  // Free memory
  GradSquareFree((GradSquare**)&((*that)->gradAutomaton.grad));
  _GrAFunDummyFree((GrAFunDummy**)&((*that)->gradAutomaton.fun));
  free(*that);
  *that = NULL;

}

// Step the GradAutomatonDummyStep
void _GradAutomatonDummyStep(GradAutomatonDummy* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Update the isStable flag
  ((GradAutomaton*)that)->isStable = true;

}

// ------------- GradAutomatonWolframOriginal

// Create a new GradAutomatonWolframOriginal
GradAutomatonWolframOriginal* GradAutomatonCreateWolframOriginal(
  const unsigned char rule,
           const long size) {

  // Allocate memory for the new GradAutomatonWolframOriginal
  GradAutomatonWolframOriginal* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GradAutomatonWolframOriginal));

  // Create the associated Grad and GrAFun
  bool diagLink = false;
  VecShort2D dim = VecShortCreateStatic2D();
```

```
VecSet(
  &dim,
  0,
  size);
VecSet(
  &dim,
  1,
  1);
Grad* grad =
  (Grad*)GradSquareCreate(
    &dim,
    diagLink);
GrAFun* fun = (GrAFun*)GrAFunCreateWolframOriginal(rule);

// Initialize the properties
long dimStatus = 1;
that->gradAutomaton =
  GradAutomatonCreateStatic(
    GradAutomatonTypeWolframOriginal,
    grad,
    fun,
    dimStatus);

// Get the index of the cell in th center of the Grad
long iCellCenter = size / 2;

// Add a GrACell to each cell of the Grad
for (
  long iCell = size;
  iCell--;) {

  GradCell* cell =
    GradCellAt(
      grad,
      iCell);

  GrACellShort* cellStatus =
    GrACellCreateShort(
      dimStatus,
      cell);

  // If it's the cell in the center of the Grad
  if (iCell == iCellCenter) {

    // Initialise the cell value to 1
    long iStatus = 0;
    short val = 1;
    GrACellSetPrevStatus(
      cellStatus,
      iStatus,
      val);
    GrACellSetCurStatus(
      cellStatus,
      iStatus,
      val);

  }

  GradCellSetData(
    cell,
    cellStatus);
```

```
  };

  // Return the new GradAutomatonWolframOriginal
  return that;

}

// Free the memory used by the GradAutomatonWolframOriginal 'that'
void GradAutomatonWolframOriginalFree(
  GradAutomatonWolframOriginal** that) {

  // If that is null
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Get the number of cells in the grad
  long nbCell = GradGetArea(GradAutomatonGrad(*that));

  // Free the GrACell attached to the cells of the Grad
  for (
    long iCell = nbCell;
    iCell--;) {

    GradCell* cell =
      GradCellAt(
        GradAutomatonGrad(*that),
        iCell);

    GrACellShort* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

  }

  // Free memory
  GradSquareFree((GradSquare**)&((*that)->gradAutomaton.grad));
  _GrAFunWolframOriginalFree(
    (GrAFunWolframOriginal**)&((*that)->gradAutomaton.fun));
  free(*that);
  *that = NULL;

}

// Step the GradAutomatonWolframOriginalStep
void _GradAutomatonWolframOriginalStep(
  GradAutomatonWolframOriginal* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }
```

```
#endif

  // Get the number of cells in the grad
  long nbCell = GradGetArea(GradAutomatonGrad(that));

  // Declare a variable to memorize if the GradAutomaton is stable
  bool isStable = true;

  // Loop on the cell
  for (
    long iCell = nbCell;
    iCell--;) {

    // Get the cell
    GrACellShort* cell =
      GradAutomatonCell(
        that,
        iCell);

    // Apply the step function to the cell
    GrAFunApply(
      GradAutomatonFun(that),
      GradAutomatonGrad(that),
      cell);

    // Update the isStable flag
    short curStatus =
      VecGet(
        GrACellCurStatus(cell),
        0);
    short prevStatus =
      VecGet(
        GrACellPrevStatus(cell),
        0);
    if (curStatus != prevStatus) {

      isStable = false;

    }

  }

  // Update the isStable flag
  ((GradAutomaton*)that)->isStable = isStable;

  // Switch all the cells
  GradAutomatonSwitchAllStatus(that);

}

// Print the GradAutomatonWolframOriginal 'that' on the FILE 'stream'
void _GradAutomatonWolframOriginalPrintln(
  GradAutomatonWolframOriginal* const that,
                                FILE* stream) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
```

```
    PBErrCatch(GradAutomatonErr);

  }

  if (stream == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'stream' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the number of cells in the grad
  long nbCell = GradGetArea(GradAutomatonGrad(that));

  fprintf(
    stream,
    "[");

  // Loop on the cell
  for (
    long iCell = 0;
    iCell < nbCell;
    ++iCell) {

    // Get the cell
    GrACellShort* cell =
      GradAutomatonCell(
        that,
        iCell);

    // Get the current status of the cell
    short status =
      VecGet(
        GrACellCurStatus(cell),
        0);

    // Print the status
    if (status == 0) {

      fprintf(
        stream,
        " ");

    } else {

      fprintf(
        stream,
        "*");

    }

  }

  fprintf(
    stream,
    "]\n");
```

```
}

// JSON encoding of GradAutomatonWolframOriginal 'that'
JSONNode* _GradAutomatonWolframOriginalEncodeAsJSON(
  const GradAutomatonWolframOriginal* const that) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Create the JSON structure
  JSONNode* json = JSONCreate();

  // Declare a buffer to convert value into string
  char val[100];

  // Encode the rule
  unsigned char rule =
    GrAFunWolframOriginalGetRule(GradAutomatonFun(that));
  sprintf(
    val,
    "%d",
    rule);
  JSONAddProp(
    json,
    "rule",
    val);

  // Encode the size
  const VecShort2D* dim = GradDim(GradAutomatonGrad(that));
  long size =
    VecGet(
      dim,
      0);
  sprintf(
    val,
    "%ld",
    size);
  JSONAddProp(
    json,
    "size",
    val);

  // Return the created JSON
  return json;

}

// Function which decode from JSON encoding 'json' to 'that'
bool _GradAutomatonWolframOriginalDecodeAsJSON(
  GradAutomatonWolframOriginal** that,
           const JSONNode* const json) {
```

```
#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (json == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'json' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // If 'that' is already allocated
  if (*that != NULL) {

    // Free memory
    GradAutomatonWolframOriginalFree(that);

  }

  // Decode the rule
  JSONNode* prop =
    JSONProperty(
      json,
      "rule");
  if (prop == NULL) {

    return false;

  }

  unsigned char rule = atoi(JSONLblVal(prop));

  // Decode the size
  prop =
    JSONProperty(
      json,
      "size");
  if (prop == NULL) {

    return false;

  }

  long size = atol(JSONLblVal(prop));

  // Create the GradAutomatonWolframOriginal
  *that =
    GradAutomatonCreateWolframOriginal(
```

```
      rule,
      size);

  // Return the success code
  return true;

}

// Save the GradAutomatonWolframOriginal 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true if the GradAutomatonWolframOriginal could be saved,
// false else
bool _GradAutomatonWolframOriginalSave(
  const GradAutomatonWolframOriginal* const that,
                                FILE* const stream,
                                 const bool compact) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (stream == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'stream' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the JSON encoding
  JSONNode* json = GradAutomatonEncodeAsJSON(that);

  // Save the JSON
  bool ret =
    JSONSave(
      json,
      stream,
      compact);

  // Free memory
  JSONFree(&json);

  // Return success code
  return ret;

}

// Load the GradAutomatonWolfraOriginal 'that' from the stream 'stream'
// If 'that' is not null the memory is first freed
```

```
// Return true if the GradAutomatonWolframOriginal could be loaded,
// false else
bool _GradAutomatonWolframOriginalLoad(
  GradAutomatonWolframOriginal** that,
                    FILE* const stream) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (stream == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'stream' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Declare a json to load the encoded data
  JSONNode* json = JSONCreate();

  // Load the whole encoded data
  bool ret =
    JSONLoad(
      json,
      stream);

  if (ret == true) {

    // Decode the data from the JSON
    ret =
      GradAutomatonDecodeAsJSON(
        that,
        json);

  }

  // Free the memory used by the JSON
  JSONFree(&json);

  // Return the success code
  return ret;

}

// ------------- GradAutomatonNeuraNet

// Create a new GradAutomatonNeuraNet with a GradSquare
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetSquare(
               const long dimStatus,
```

```
const VecShort2D* const dimGrad,
             const bool diagLink,
             const long nbHiddenLayers) {

// Allocate memory for the new GradAutomatonNeuraNet
GradAutomatonNeuraNet* that =
  PBErrMalloc(
    GradAutomatonErr,
    sizeof(GradAutomatonNeuraNet));

// Create the associated Grad and GrAFun
Grad* grad =
  (Grad*)GradSquareCreate(
    dimGrad,
    diagLink);
int nbIn = 0;
if (diagLink == true) {

  nbIn = dimStatus * 9;

} else {

  nbIn = dimStatus * 5;

}

int nbOut = dimStatus;
VecLong* hiddenLayers = VecLongCreate(nbHiddenLayers);
for (
  int iLayer = nbHiddenLayers;
  iLayer--;) {

  VecSet(
    hiddenLayers,
    iLayer,
    nbIn);

}

GrAFun* fun =
  (GrAFun*)GrAFunCreateNeuraNet(
    nbIn,
    nbOut,
    hiddenLayers);

// Initialize the properties
that->nbHiddenLayers = nbHiddenLayers;
that->gradAutomaton =
  GradAutomatonCreateStatic(
    GradAutomatonTypeNeuraNet,
    grad,
    fun,
    dimStatus);

// Add a GrACell to each cell of the Grad
long area = GradGetArea(GradAutomatonGrad(that));
for (
  long iCell = area;
  iCell--;) {

  GradCell* cell =
    GradCellAt(
```

```
        grad,
        iCell);

    GrACellFloat* cellStatus =
      GrACellCreateFloat(
        dimStatus,
        cell);

    GradCellSetData(
      cell,
      cellStatus);

  }

  // Free memory
  VecFree(&hiddenLayers);

  // Return the new GradAutomatonNeuraNet
  return that;

}

// Create a new GradAutomatonNeuraNet with a GradHexa
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetHexa(
               const long dimStatus,
  const VecShort2D* const dimGrad,
       const GradHexaType gradType,
               const long nbHiddenLayers) {

  // Allocate memory for the new GradAutomatonNeuraNet
  GradAutomatonNeuraNet* that =
    PBErrMalloc(
      GradAutomatonErr,
      sizeof(GradAutomatonNeuraNet));

  // Create the associated Grad and GrAFun
  Grad* grad = NULL;
  switch (gradType) {

    case GradHexaTypeEvenQ:
      grad = (Grad*)GradHexaCreateEvenQ(
        dimGrad);
      break;
    case GradHexaTypeEvenR:
      grad = (Grad*)GradHexaCreateEvenR(
        dimGrad);
      break;
    case GradHexaTypeOddQ:
      grad = (Grad*)GradHexaCreateOddQ(
        dimGrad);
      break;
    case GradHexaTypeOddR:
      grad = (Grad*)GradHexaCreateOddR(
        dimGrad);
      break;
    default:
      break;

  }

  int nbIn = dimStatus * 6;
  int nbOut = dimStatus;
```

```
  VecLong* hiddenLayers = VecLongCreate(nbHiddenLayers);
  for (
    int iLayer = nbHiddenLayers;
    iLayer--;) {

    VecSet(
      hiddenLayers,
      iLayer,
      nbIn);

  }

  GrAFun* fun =
    (GrAFun*)GrAFunCreateNeuraNet(
      nbIn,
      nbOut,
      hiddenLayers);

  // Initialize the properties
  that->nbHiddenLayers = nbHiddenLayers;
  that->gradAutomaton =
    GradAutomatonCreateStatic(
      GradAutomatonTypeNeuraNet,
      grad,
      fun,
      dimStatus);

  // Add a GrACell to each cell of the Grad
  long area = GradGetArea(GradAutomatonGrad(that));
  for (
    long iCell = area;
    iCell--;) {

    GradCell* cell =
      GradCellAt(
        grad,
        iCell);

    GrACellFloat* cellStatus =
      GrACellCreateFloat(
        dimStatus,
        cell);

    GradCellSetData(
      cell,
      cellStatus);

  }

  // Free memory
  VecFree(&hiddenLayers);

  // Return the new GradAutomatonNeuraNet
  return that;

}

// Free the memory used by the GradAutomatonNeuraNet 'that'
void GradAutomatonNeuraNetFree(
  GradAutomatonNeuraNet** that) {

  // If that is null
```

```
  if (that == NULL || *that == NULL) {

    // Do nothing
    return;

  }

  // Free the GrACell attached to the cells of the Grad
  long area = GradGetArea(GradAutomatonGrad(*that));
  for (
    long iCell = area;
    iCell--;) {

    GradCell* cell =
      GradCellAt(
        GradAutomatonGrad(*that),
        iCell);

    GrACellFloat* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

  }

  // Free the memory used by the Grad
  GradSquareFree((GradSquare**)&((*that)->gradAutomaton.grad));

  // Free the memory used by the GrAFun
  _GrAFunNeuraNetFree((GrAFunNeuraNet**)&((*that)->gradAutomaton.fun));

  // Free memory
  free(*that);
  *that = NULL;

}

// Step the GradAutomatonNeuraNetStep
void _GradAutomatonNeuraNetStep(GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the number of cells in the grad
  long nbCell = GradGetArea(GradAutomatonGrad(that));

  // Declare a variable to memorize if the GradAutomaton is stable
  bool isStable = true;

  // Loop on the cell
  for (
    long iCell = nbCell;
    iCell--;) {
```

```
    // Get the cell
    GrACellFloat* cell =
      GradAutomatonCell(
        that,
        iCell);

    // Apply the step function to the cell
    GrAFunApply(
      GradAutomatonFun(that),
      GradAutomatonGrad(that),
      cell);

    // Update the isStable flag
    VecFloat* curStatus = GrACellCurStatus(cell);
    VecFloat* prevStatus = GrACellPrevStatus(cell);
    bool isSame =
      VecIsEqual(
        curStatus,
        prevStatus);
    if (isSame == false) {

      isStable = false;

    }

  }

  // Update the isStable flag
  ((GradAutomaton*)that)->isStable = isStable;

  // Switch all the cells
  GradAutomatonSwitchAllStatus(that);

}

// JSON encoding of GradAutomatonNeuraNet 'that'
JSONNode* _GradAutomatonNeuraNetEncodeAsJSON(
  const GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Create the JSON structure
  JSONNode* json = JSONCreate();

  // Declare a buffer to convert value into string
  char val[100];

  // Encode the type of the Grad
  GradType typeGrad = GradGetType(GradAutomatonGrad(that));
```

```
sprintf(
  val,
  "%d",
  typeGrad);
JSONAddProp(
  json,
  "typeGrad",
  val);

// Encode the dimensions of the Grad
const VecShort2D* dimGrad = GradDim(GradAutomatonGrad(that));
JSONNode* dimGradJSON = VecEncodeAsJSON((VecShort*)dimGrad);
JSONAddProp(
  json,
  "dimGrad",
  dimGradJSON);

// Encode the dimensions of the status
long dimStatus = GradAutomatonGetDimStatus(that);
sprintf(
  val,
  "%ld",
  dimStatus);
JSONAddProp(
  json,
  "dimStatus",
  val);

// Encode the number of hidden layers
long nbHiddenLayers = GradAutomatonNeuraNetGetNbHiddenLayers(that);
sprintf(
  val,
  "%ld",
  nbHiddenLayers);
JSONAddProp(
  json,
  "nbHiddenLayers",
  val);

// If the associated grad is of type hexa
if (typeGrad == GradTypeHexa) {

  // Encode the type of GradHexa
  GradHexaType typeGradHexa =
    GradHexaGetType((GradHexa*)GradAutomatonGrad(that));
  sprintf(
    val,
    "%d",
    typeGradHexa);
  JSONAddProp(
    json,
    "typeGradHexa",
    val);

// Else, if the associated grad is of type hexa
} else if (typeGrad == GradTypeSquare) {

  // Encode the diagonal link flag
  bool diagLink =
    GradSquareHasDiagonalLink((GradSquare*)GradAutomatonGrad(that));
  sprintf(
    val,
```

```
      "%d",
      diagLink);
    JSONAddProp(
      json,
      "diagLink",
      val);

  }

  // Encode the NeuraNet
  const NeuraNet* nn =
    GrAFunNeuraNetNN((GrAFunNeuraNet*)(GradAutomatonFun(that)));
  JSONNode* nnJSON = NNEncodeAsJSON(nn);
  JSONAddProp(
    json,
    "nn",
    nnJSON);

  // Return the created JSON
  return json;

}

// Function which decode from JSON encoding 'json' to 'that'
bool _GradAutomatonNeuraNetDecodeAsJSON(
  GradAutomatonNeuraNet** that,
    const JSONNode* const json) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (json == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'json' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // If 'that' is already allocated
  if (*that != NULL) {

    // Free memory
    GradAutomatonNeuraNetFree(that);

  }

  // Decode the type of grad
  JSONNode* prop =
```

```
  JSONProperty(
    json,
    "typeGrad");
if (prop == NULL) {

  return false;

}

GradType typeGrad = atoi(JSONLblVal(prop));

// Decode the dimension of the status
prop =
  JSONProperty(
    json,
    "dimStatus");
if (prop == NULL) {

  return false;

}

long dimStatus = atol(JSONLblVal(prop));

// Decode the dimensions of the Grad
prop =
  JSONProperty(
    json,
    "dimGrad");
if (prop == NULL) {

  return false;

}

VecShort2D* dimGrad = NULL;
bool ret =
  VecDecodeAsJSON(
    (VecShort**)(&dimGrad),
    prop);
if (ret == false) {

  return false;

}

// Decode the number of hidden layers
prop =
  JSONProperty(
    json,
    "nbHiddenLayers");
if (prop == NULL) {

  return false;

}

long nbHiddenLayers = atol(JSONLblVal(prop));

// If the associated grad is of type hexa
if (typeGrad == GradTypeHexa) {
```

```
  // Decode the type of grad hexa
  prop =
    JSONProperty(
      json,
      "typeGradHexa");
  if (prop == NULL) {

    return false;

  }

  GradHexaType typeGradHexa = atoi(JSONLblVal(prop));

  // Create the GradAutomatonNeuraNet
  *that =
    GradAutomatonCreateNeuraNetHexa(
      dimStatus,
      dimGrad,
      typeGradHexa,
      nbHiddenLayers);

// Else, if the associated grad is of type square
} else if (typeGrad == GradTypeSquare) {

  // Decode the diagonal link flag
  prop =
    JSONProperty(
      json,
      "diagLink");
  if (prop == NULL) {

    return false;

  }

  bool diagLink = atoi(JSONLblVal(prop));

  // Create the GradAutomatonNeuraNet
  *that =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      dimGrad,
      diagLink,
      nbHiddenLayers);

} else {

  return false;

}

// Load the NeuraNet
prop =
  JSONProperty(
    json,
    "nn");
if (prop == NULL) {

  return false;

}
```

```
  ret =
    NNDecodeAsJSON(
      &(((GrAFunNeuraNet*)GradAutomatonFun(*that))->nn),
      prop);
  if (ret == false) {

    return false;

  }

  // Free memory
  VecFree((VecShort**)(&dimGrad));

  // Return the success code
  return true;

}

// Save the GradAutomatonNeuraNet 'that' to the stream 'stream'
// If 'compact' equals true it saves in compact form, else it saves in
// readable form
// Return true if the GradAutomatonNeuraNet could be saved,
// false else
bool _GradAutomatonNeuraNetSave(
  const GradAutomatonNeuraNet* const that,
                         FILE* const stream,
                          const bool compact) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (stream == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'stream' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the JSON encoding
  JSONNode* json = GradAutomatonEncodeAsJSON(that);

  // Save the JSON
  bool ret =
    JSONSave(
      json,
      stream,
      compact);
```

```
  // Free memory
  JSONFree(&json);

  // Return success code
  return ret;

}

// Load the GradAutomatonWolfraOriginal 'that' from the stream 'stream'
// If 'that' is not null the memory is first freed
// Return true if the GradAutomatonNeuraNet could be loaded,
// false else
bool _GradAutomatonNeuraNetLoad(
  GradAutomatonNeuraNet** that,
              FILE* const stream) {

#if BUILDMODE == 0

  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (stream == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'stream' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Declare a json to load the encoded data
  JSONNode* json = JSONCreate();

  // Load the whole encoded data
  bool ret =
    JSONLoad(
      json,
      stream);

  if (ret == true) {

    // Decode the data from the JSON
    ret =
      GradAutomatonDecodeAsJSON(
        that,
        json);

  }

  // Free the memory used by the JSON
  JSONFree(&json);
```

```
  // Return the success code
  return ret;

}
```

3.2 gradautomaton-inline.c

```
// ============ GRADAUTOMATON_INLINE.C ================

// -------------- GrACell

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

// Switch the current status of the GrACell 'that'
#if BUILDMODE != 0
static inline
#endif
void _GrACellSwitchStatus(GrACell* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  that->curStatus = 1 - that->curStatus;

}

// Return the current status of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
VecShort* _GrACellShortCurStatus(const GrACellShort* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->status[that->gradAutomatonCell.curStatus];

}

// Return the current status of the GrACellFloat 'that'
```

```
#if BUILDMODE != 0
static inline
#endif
VecFloat* _GrACellFloatCurStatus(const GrACellFloat* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->status[that->gradAutomatonCell.curStatus];

}

// Return the previous status of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
VecShort* _GrACellShortPrevStatus(const GrACellShort* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->status[1 - that->gradAutomatonCell.curStatus];

}

// Return the previous status of the GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
VecFloat* _GrACellFloatPrevStatus(const GrACellFloat* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }
```

```
#endif

  return that->status[1 - that->gradAutomatonCell.curStatus];

}

// Return the 'iVal'-th value of the previous status of the
// GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
short _GrACellShortGetPrevStatus(
  const GrACellShort* const that,
        const unsigned long iVal) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return VecGet(
    GrACellPrevStatus(that),
    iVal);

}

// Return the 'iVal'-th value of the previous status of the
// GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
float _GrACellFloatGetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return VecGet(
    GrACellPrevStatus(that),
    iVal);

}
```

```
// Set the 'iVal'-th value of the previous status of the
// GrACellShort 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellShortSetPrevStatus(
  const GrACellShort* const that,
        const unsigned long iVal,
                const short val) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  VecSet(
    GrACellPrevStatus(that),
    iVal,
    val);

}

// Set the 'iVal'-th value of the previous status of the
// GrACellFloat 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellFloatSetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal,
                const float val) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  VecSet(
    GrACellPrevStatus(that),
    iVal,
    val);

}

// Return the 'iVal'-th value of the current status of the
// GrACellShort 'that'
```

```
#if BUILDMODE != 0
static inline
#endif
short _GrACellShortGetCurStatus(
  const GrACellShort* const that,
        const unsigned long iVal) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return VecGet(
    GrACellCurStatus(that),
    iVal);

}

// Return the 'iVal'-th value of the current status of the
// GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
float _GrACellFloatGetCurStatus(
  const GrACellFloat* const that,
        const unsigned long iVal) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return VecGet(
    GrACellCurStatus(that),
    iVal);

}

// Set the 'iVal'-th value of the current status of the
// GrACellShort 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellShortSetCurStatus(
  const GrACellShort* const that,
        const unsigned long iVal,
```

```
               const short val) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  VecSet(
    GrACellCurStatus(that),
    iVal,
    val);

}

// Set the 'iVal'-th value of the current status of the
// GrACellFloat 'that' to 'val'
#if BUILDMODE != 0
static inline
#endif
void _GrACellFloatSetCurStatus(
  const GrACellFloat* const that,
        const unsigned long iVal,
               const float val) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  VecSet(
    GrACellCurStatus(that),
    iVal,
    val);

}

// Return the GradCell of the GrACellShort 'that'
#if BUILDMODE != 0
static inline
#endif
GradCell* _GrACellShortGradCell(const GrACellShort* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->gradAutomatonCell.gradCell;

}

// Return the GradCell of the GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
GradCell* _GrACellFloatGradCell(const GrACellFloat* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->gradAutomatonCell.gradCell;

}

// -------------- GrAFun

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

// Return the type of the GrAFun 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunType _GrAFunGetType(const GrAFun* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->type;

}
```

```
// -------------- GrAFunWolframOriginal

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

// Return the rule of the GrAFunWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
unsigned char GrAFunWolframOriginalGetRule(
  GrAFunWolframOriginal* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->rule;

}

// -------------- GrAFunNeuraNet

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

// Return the NeuraNet of the GrAFunNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
NeuraNet* GrAFunNeuraNetNN(
  GrAFunNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  return that->nn;

}

// -------------- GradAutomaton

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

// Return the Grad of the GradAutomaton 'that'
```

```
#if BUILDMODE != 0
static inline
#endif
Grad* _GradAutomatonGrad(const GradAutomaton* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the Grad
  return that->grad;

}

// Return the GrACellShort at position 'pos' for the
// GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
GrACell* _GradAutomatonCellPos(
     GradAutomaton* const that,
  const VecShort2D* const pos) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (pos == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'pos' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      pos);

  // Return the GrACellShort associated to the cell
```

```
  return (GrACell*)GradCellData(cell);

}

// Return the GrACellShort at index 'iCell' for the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
GrACell* _GradAutomatonCellIndex(
  GradAutomaton* const that,
            const long iCell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      iCell);

  // Return the GrACellShort associated to the cell
  return (GrACell*)GradCellData(cell);

}

// Return the dimension of the status of the GradAutomaton 'that'
#if BUILDMODE != 0
static inline
#endif
long _GradAutomatonGetDimStatus(const GradAutomaton* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the dimension of the status
  return that->dimStatus;

}

// Return the flag isStable of the GradAutomaton 'that'
#if BUILDMODE != 0
```

```
static inline
#endif
bool _GradAutomatonIsStable(const GradAutomaton* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the flag isStable
  return that->isStable;

}

// -------------- GradAutomatonDummy

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

// Return the Grad of the GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GradSquare* _GradAutomatonDummyGrad(
  const GradAutomatonDummy* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the Grad
  return (GradSquare*)(((GradAutomaton*)that)->grad);

}

// Return the GrAFun of the GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunDummy* _GradAutomatonDummyFun(
  const GradAutomatonDummy* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the GrAFun
  return (GrAFunDummy*)(((GradAutomaton*)that)->fun);

}

// Return the GrACellShort at position 'pos' for the
// GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonDummyCellPos(
  GradAutomatonDummy* const that,
    const VecShort2D* const pos) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (pos == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'pos' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      pos);

  // Return the GrACellShort associated to the cell
  return (GrACellShort*)GradCellData(cell);

}

// Return the GrACellShort at index 'iCell' for the
// GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
```

```
GrACellShort* _GradAutomatonDummyCellIndex(
  GradAutomatonDummy* const that,
                const long iCell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      iCell);

  // Return the GrACellShort associated to the cell
  return (GrACellShort*)GradCellData(cell);

}

// -------------- GradAutomatonWolframOriginal

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

// Return the Grad of the GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GradSquare* _GradAutomatonWolframOriginalGrad(
  const GradAutomatonWolframOriginal* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the Grad
  return (GradSquare*)(((GradAutomaton*)that)->grad);

}

// Return the GrAFun of the GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunWolframOriginal* _GradAutomatonWolframOriginalFun(
```

```
  const GradAutomatonWolframOriginal* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the GrAFun
  return (GrAFunWolframOriginal*)(((GradAutomaton*)that)->fun);

}

// Return the GrACellShort at position 'pos' for the
// GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellPos(
  GradAutomatonWolframOriginal* const that,
              const VecShort2D* const pos) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (pos == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'pos' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      pos);

  // Return the GrACellShort associated to the cell
  return (GrACellShort*)GradCellData(cell);

}
```

```
// Return the GrACellShort at index 'iCell' for the
// GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellIndex(
  GradAutomatonWolframOriginal* const that,
                            const long iCell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      iCell);

  // Return the GrACellShort associated to the cell
  return (GrACellShort*)GradCellData(cell);

}

// -------------- GradAutomatonNeuraNet

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

// Return the Grad of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
Grad* _GradAutomatonNeuraNetGrad(
  const GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the Grad
  return ((GradAutomaton*)that)->grad;

}
```

```
// Return the type of Grad of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GradType GradAutomatonNeuraNetGetGradType(
  GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the type of the Grad
  return GradGetType(((GradAutomaton*)that)->grad);

}

// Return the GrAFun of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrAFunNeuraNet* _GradAutomatonNeuraNetFun(
  const GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the GrAFun
  return (GrAFunNeuraNet*)(((GradAutomaton*)that)->fun);

}

// Return the GrACellFloat at position 'pos' for the
// GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellFloat* _GradAutomatonNeuraNetCellPos(
  GradAutomatonNeuraNet* const that,
       const VecShort2D* const pos) {

#if BUILDMODE == 0
  if (that == NULL) {
```

```
    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

  if (pos == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'pos' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      pos);

  // Return the GrACellFloat associated to the cell
  return (GrACellFloat*)GradCellData(cell);

}

// Return the GrACellFloat at index 'iCell' for the
// GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
GrACellFloat* _GradAutomatonNeuraNetCellIndex(
  GradAutomatonNeuraNet* const that,
                    const long iCell) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
    GradCellAt(
      GradAutomatonGrad(that),
      iCell);

  // Return the GrACellFloat associated to the cell
  return (GrACellFloat*)GradCellData(cell);
```

```
}

// Return the number of hidden layers of the GradAutomatonNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
long GradAutomatonNeuraNetGetNbHiddenLayers(
  const GradAutomatonNeuraNet* const that) {

#if BUILDMODE == 0
  if (that == NULL) {

    GradAutomatonErr->_type = PBErrTypeNullPointer;
    sprintf(
      GradAutomatonErr->_msg,
      "'that' is null");
    PBErrCatch(GradAutomatonErr);

  }

#endif

  // Return the number of hidden layers
  return that->nbHiddenLayers;

}
```

4 Makefile

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

all: pbmake_wget main

# Automatic installation of the repository PBMake in the parent folder
pbmake_wget:
if [ ! -d ../PBMake ]; then wget https://github.com/BayashiPascal/PBMake/archive/master.zip; unzip master.zip; rm -f

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

# Rules to make the executable
repo=gradautomaton
$($(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 "pberr.h"
#include "gradautomaton.h"

#define RANDOMSEED 0

void UnitTestGrACellCreateFree(void) {

  int dim = 2;
  GradCell gradCell;
  GrACellShort* cellShort =
    GrACellCreateShort(
      dim,
      &gradCell);
  if (
    cellShort == NULL ||
    VecGetDim(cellShort->status[0]) != dim ||
    VecGetDim(cellShort->status[1]) != dim ||
    cellShort->gradAutomatonCell.curStatus != 0 ||
    cellShort->gradAutomatonCell.gradCell != &gradCell) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellCreateShort failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellShort);
  if (cellShort != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFloat* cellFloat =
    GrACellCreateFloat(
      dim,
      &gradCell);
  if (
    cellFloat == NULL ||
    VecGetDim(cellFloat->status[0]) != dim ||
    VecGetDim(cellFloat->status[1]) != dim ||
    cellFloat->gradAutomatonCell.curStatus != 0 ||
```

```
    cellFloat->gradAutomatonCell.gradCell != &gradCell) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellCreateFloat failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellFloat);
  if (cellFloat != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellFloatFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGrACellCreateFree OK\n");

}

void UnitTestGrACellSwitchStatus(void) {

  int dim = 2;
  GrACellShort* cellShort =
    GrACellCreateShort(
      dim,
      NULL);
  GrACellSwitchStatus(cellShort);
  if (cellShort->gradAutomatonCell.curStatus != 1) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortSwitchStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellSwitchStatus(cellShort);
  if (cellShort->gradAutomatonCell.curStatus != 0) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortSwitchStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellShort);

  GrACellFloat* cellFloat =
    GrACellCreateFloat(
      dim,
      NULL);
  GrACellSwitchStatus(cellFloat);
  if (cellFloat->gradAutomatonCell.curStatus != 1) {
```

```
    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellFloatSwitchStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellSwitchStatus(cellFloat);
  if (cellFloat->gradAutomatonCell.curStatus != 0) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellFloatSwitchStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellFloat);

  printf("UnitTestGrACellSwitchStatus OK\n");

}

void UnitTestGrACellCurPrevStatus(void) {

  int dim = 2;
  GrACellShort* cellShort =
    GrACellCreateShort(
      dim,
      NULL);
  if (cellShort->status[0] != GrACellCurStatus(cellShort)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (cellShort->status[1] != GrACellPrevStatus(cellShort)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellShort);

  GrACellFloat* cellFloat =
    GrACellCreateFloat(
      dim,
      NULL);
  if (cellFloat->status[0] != GrACellCurStatus(cellFloat)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
```

```
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellFloatCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (cellFloat->status[1] != GrACellPrevStatus(cellFloat)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellFloatCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrACellFree(&cellFloat);

  printf("UnitTestGrACellCurPrevStatus OK\n");

}

void UnitTestGrACellGetSet(void) {

  int dim = 1;
  GradCell gradCell;
  GrACellShort* cellShort =
    GrACellCreateShort(
      dim,
      &gradCell);
  GrACellSetCurStatus(
    cellShort,
    0,
    1);
  short curStatusS =
    VecGet(
      GrACellCurStatus(cellShort),
      0);
  if (curStatusS != 1) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortSetCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }

  curStatusS =
    GrACellGetCurStatus(
      cellShort,
      0);
  if (curStatusS != 1) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrACellShortGetCurStatus failed");
    PBErrCatch(GradAutomatonErr);

  }
```

```
GrACellSetPrevStatus(
  cellShort,
  0,
  1);
short prevStatusS =
  VecGet(
    GrACellPrevStatus(cellShort),
    0);
if (prevStatusS != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellShortSetPrevStatus failed");
  PBErrCatch(GradAutomatonErr);

}

prevStatusS =
  GrACellGetPrevStatus(
    cellShort,
    0);
if (prevStatusS != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellShortGetPrevStatus failed");
  PBErrCatch(GradAutomatonErr);

}

if (GrACellGradCell(cellShort) != &gradCell) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellShortGradCell failed");
  PBErrCatch(GradAutomatonErr);

}

GrACellFree(&cellShort);

GrACellFloat* cellFloat =
  GrACellCreateFloat(
    dim,
    &gradCell);
GrACellSetCurStatus(
  cellFloat,
  0,
  1);
float curStatusF =
  VecGet(
    GrACellCurStatus(cellFloat),
    0);
if (curStatusF != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
```

```
    "GrACellFloatSetCurStatus failed");
  PBErrCatch(GradAutomatonErr);

}

curStatusF =
  GrACellGetCurStatus(
    cellFloat,
    0);
if (curStatusF != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellFloatGetCurStatus failed");
  PBErrCatch(GradAutomatonErr);

}

GrACellSetPrevStatus(
  cellFloat,
  0,
  1);
float prevStatusF =
  VecGet(
    GrACellPrevStatus(cellFloat),
    0);
if (prevStatusF != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellFloatSetPrevStatus failed");
  PBErrCatch(GradAutomatonErr);

}

prevStatusF =
  GrACellGetPrevStatus(
    cellFloat,
    0);
if (prevStatusF != 1) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellFloatGetPrevStatus failed");
  PBErrCatch(GradAutomatonErr);

}

if (GrACellGradCell(cellFloat) != &gradCell) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GrACellFloatGradCell failed");
  PBErrCatch(GradAutomatonErr);

}

GrACellFree(&cellFloat);
```

```
  printf("UnitTestGrACellCurGetSet OK\n");

}

void UnitTestGrACell(void) {

  UnitTestGrACellCreateFree();
  UnitTestGrACellSwitchStatus();
  UnitTestGrACellCurPrevStatus();
  UnitTestGrACellGetSet();
  printf("UnitTestGrACell OK\n");

}

void UnitTestGrAFunDummyCreateFree(void) {

  GrAFunDummy* fun = GrAFunCreateDummy();
  if (
    fun == NULL ||
    fun->grAFun.type != GrAFunTypeDummy) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunCreateDummy failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);
  if (fun != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGrAFunDummyCreateFree OK\n");

}

void UnitTestGrAFunDummyGetType(void) {

  GrAFunDummy* fun = GrAFunCreateDummy();
  if (GrAFunGetType(fun) != GrAFunTypeDummy) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunDummyGetType failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);

  printf("UnitTestGrAFunDummyGetType OK\n");
```

```
}

void UnitTestGrAFunDummy(void) {

  UnitTestGrAFunDummyCreateFree();
  UnitTestGrAFunDummyGetType();
  printf("UnitTestGrAFunDummy OK\n");

}

void UnitTestGrAFunWolframOriginalCreateFree(void) {

  unsigned char rule = 42;
  GrAFunWolframOriginal* fun = GrAFunCreateWolframOriginal(rule);
  if (
    fun == NULL ||
    fun->grAFun.type != GrAFunTypeWolframOriginal ||
    fun->rule != rule) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunCreateWolframOriginal failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);
  if (fun != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGrAFunWolframOriginalCreateFree OK\n");

}

void UnitTestGrAFunWolframOriginalGetType(void) {

  unsigned char rule = 42;
  GrAFunWolframOriginal* fun = GrAFunCreateWolframOriginal(rule);
  if (GrAFunGetType(fun) != GrAFunTypeWolframOriginal) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunWolframOriginalGetType failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);

  printf("UnitTestGrAFunWolframOriginalGetType OK\n");

}
```

```
void UnitTestGrAFunWolframOriginalGetRule(void) {

  unsigned char rule = 42;
  GrAFunWolframOriginal* fun = GrAFunCreateWolframOriginal(rule);
  if (GrAFunWolframOriginalGetRule(fun) != rule) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunWolframOriginalGetRule failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);

  printf("UnitTestGrAFunWolframOriginalGetRule OK\n");

}

void UnitTestGrAFunWolframOriginal(void) {

  UnitTestGrAFunWolframOriginalCreateFree();
  UnitTestGrAFunWolframOriginalGetType();
  UnitTestGrAFunWolframOriginalGetRule();
  printf("UnitTestGrAFunWolframOriginal OK\n");

}

void UnitTestGrAFunNeuraNetCreateFree(void) {

  int nbIn = 1;
  int nbOut = 1;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  GrAFunNeuraNet* fun =
    GrAFunCreateNeuraNet(
      nbIn,
      nbOut,
      hiddenLayers);
  if (
    fun == NULL ||
    fun->grAFun.type != GrAFunTypeNeuraNet ||
    NNGetNbInput(fun->nn) != nbIn ||
    NNGetNbOutput(fun->nn) != nbOut) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunCreateNeuraNet failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);
  if (fun != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
```

```
      GradAutomatonErr->_msg,
      "GrAFunFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  VecFree(&hiddenLayers);

  printf("UnitTestGrAFunNeuraNetCreateFree OK\n");

}

void UnitTestGrAFunNeuraNetGetType(void) {

  int nbIn = 1;
  int nbOut = 1;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  GrAFunNeuraNet* fun =
    GrAFunCreateNeuraNet(
      nbIn,
      nbOut,
      hiddenLayers);
  if (GrAFunGetType(fun) != GrAFunTypeNeuraNet) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GrAFunNeuraNetGetType failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);
  VecFree(&hiddenLayers);

  printf("UnitTestGrAFunNeuraNetGetType OK\n");

}

void UnitTestGrAFunNeuraNetNN(void) {

  int nbIn = 1;
  int nbOut = 1;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  GrAFunNeuraNet* fun =
    GrAFunCreateNeuraNet(
      nbIn,
      nbOut,
      hiddenLayers);
  if (GrAFunNeuraNetNN(fun) != fun->nn) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
```

```
      "GrAFunNeuraNetNN failed");
    PBErrCatch(GradAutomatonErr);

  }

  GrAFunFree(&fun);
  VecFree(&hiddenLayers);

  printf("UnitTestGrAFunNeuraNetNN OK\n");

}

void UnitTestGrAFunNeuraNet(void) {

  UnitTestGrAFunNeuraNetCreateFree();
  UnitTestGrAFunNeuraNetGetType();
  UnitTestGrAFunNeuraNetNN();
  printf("UnitTestGrAFunNeuraNet OK\n");

}

void UnitTestGrAFun(void) {

  UnitTestGrAFunDummy();
  UnitTestGrAFunWolframOriginal();
  UnitTestGrAFunNeuraNet();
  printf("UnitTestGrAFun OK\n");

}

void UnitTestGradAutomatonDummyCreateFree(void) {

  GradAutomatonDummy* ga = GradAutomatonCreateDummy();
  if (
    ga == NULL ||
    ga->gradAutomaton.grad == NULL ||
    ga->gradAutomaton.fun == NULL ||
    ga->gradAutomaton.type != GradAutomatonTypeDummy ||
    ga->gradAutomaton.isStable != false) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonCreateDummy failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonDummyFree(&ga);
  if (ga != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonDummyFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGradAutomatonDummyCreateFree OK\n");

}
```

```
void UnitTestGradAutomatonDummyGet(void) {

  GradAutomatonDummy* ga = GradAutomatonCreateDummy();
  if (GradAutomatonGrad(ga) != (GradSquare*)(ga->gradAutomaton.grad)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonDummyGrad failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (GradAutomatonFun(ga) != (GrAFunDummy*)(ga->gradAutomaton.fun)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonDummyFun failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (GradAutomatonIsStable(ga) != ga->gradAutomaton.isStable) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonDummyIsStable failed");
    PBErrCatch(GradAutomatonErr);

  }

  for (
    long i = 0;
    i < 4;
    ++i) {

    void* cellA =
      GradAutomatonCell(
        ga,
        i);
    void* cellB =
      GradCellAt(
        ga->gradAutomaton.grad,
        i);
    if (cellA != GradCellData(cellB)) {

      GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
      sprintf(
        GradAutomatonErr->_msg,
        "GradAutomatonDummyCellIndex failed");
      PBErrCatch(GradAutomatonErr);

    }

  }

  VecShort2D dim = VecShortCreateStatic2D(2);
  VecSet(
    &dim,
```

```
    0,
    2);
  VecSet(
    &dim,
    1,
    2);
  VecShort2D pos = VecShortCreateStatic2D(2);
  bool flag = true;
  do {

    void* cellA =
      GradAutomatonCell(
        ga,
        &pos);
    void* cellB =
      GradCellAt(
        ga->gradAutomaton.grad,
        &pos);
    if (cellA != GradCellData(cellB)) {

      GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
      sprintf(
        GradAutomatonErr->_msg,
        "GradAutomatonDummyCellPos failed");
      PBErrCatch(GradAutomatonErr);

    }

    flag =
      VecStep(
        &pos,
        &dim);

  } while(flag);

  GradAutomatonDummyFree(&ga);

  printf("UnitTestGradAutomatonDummyGet OK\n");

}

void UnitTestGradAutomatonDummyStep(void) {

  GradAutomatonDummy* ga = GradAutomatonCreateDummy();

  GradAutomatonStep(ga);

  if (GradAutomatonIsStable(ga) != true) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonDummyStep failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonDummyFree(&ga);

  printf("UnitTestGradAutomatonDummyStep OK\n");

}
```

```
void UnitTestGradAutomatonDummy(void) {

  UnitTestGradAutomatonDummyCreateFree();
  UnitTestGradAutomatonDummyGet();
  UnitTestGradAutomatonDummyStep();
  printf("UnitTestGradAutomatonDummy OK\n");

}

void UnitTestGradAutomatonWolframOriginalCreateFree(void) {

  unsigned char rule = 42;
  long size = 20;
  GradAutomatonWolframOriginal* ga =
    GradAutomatonCreateWolframOriginal(
      rule,
      size);
  if (
    ga == NULL ||
    ga->gradAutomaton.grad == NULL ||
    ga->gradAutomaton.fun == NULL ||
    ga->gradAutomaton.type != GradAutomatonTypeWolframOriginal ||
    ga->gradAutomaton.isStable != false ||
    ((GrAFunWolframOriginal*)(ga->gradAutomaton.fun))->rule != rule ||
    ga->gradAutomaton.grad->_dim._val[0] != size ||
    ga->gradAutomaton.grad->_dim._val[1] != 1) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonCreateWolframOriginal failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonWolframOriginalFree(&ga);
  if (ga != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonWolframOriginalFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGradAutomatonWolframOriginalCreateFree OK\n");

}

void UnitTestGradAutomatonWolframOriginalGet(void) {

  unsigned char rule = 42;
  long size = 20;
  GradAutomatonWolframOriginal* ga =
    GradAutomatonCreateWolframOriginal(
      rule,
      size);
  if (GradAutomatonGrad(ga) != (GradSquare*)(ga->gradAutomaton.grad)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
```

```
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonWolframOriginalGrad failed");
  PBErrCatch(GradAutomatonErr);

}

if ((void*)GradAutomatonFun(ga) != ga->gradAutomaton.fun) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonWolframOriginalFun failed");
  PBErrCatch(GradAutomatonErr);

}

if (GradAutomatonIsStable(ga) != ga->gradAutomaton.isStable) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonWolframOriginalIsStable failed");
  PBErrCatch(GradAutomatonErr);

}

for (
  long i = 0;
  i < 4;
  ++i) {

  void* cellA =
    GradAutomatonCell(
      ga,
      i);
  void* cellB =
    GradCellAt(
      ga->gradAutomaton.grad,
      i);
  if (cellA != GradCellData(cellB)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonWolframOriginalCellIndex failed");
    PBErrCatch(GradAutomatonErr);

  }

}

VecShort2D dim = VecShortCreateStatic2D(2);
VecSet(
  &dim,
  0,
  size);
VecSet(
  &dim,
  1,
  1);
VecShort2D pos = VecShortCreateStatic2D(2);
```

```
  bool flag = true;
  do {

    void* cellA =
      GradAutomatonCell(
        ga,
        &pos);
    void* cellB =
      GradCellAt(
        ga->gradAutomaton.grad,
        &pos);
    if (cellA != GradCellData(cellB)) {

      GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
      sprintf(
        GradAutomatonErr->_msg,
        "GradAutomatonWolframOriginalCellPos failed");
      PBErrCatch(GradAutomatonErr);

    }

    flag =
      VecStep(
        &pos,
        &dim);

  } while(flag);

  GradAutomatonWolframOriginalFree(&ga);

  printf("UnitTestGradAutomatonWolframOriginalGet OK\n");

}

void UnitTestGradAutomatonWolframOriginalStepPrintln(void) {

  unsigned char rule = 30;
  long size = 100;
  GradAutomatonWolframOriginal* ga =
    GradAutomatonCreateWolframOriginal(
      rule,
      size);

  GradAutomatonPrintln(
    ga,
    stdout);

  for (
    long iStep = 0;
    iStep < size;
    ++iStep) {

    GradAutomatonStep(ga);

    GradAutomatonPrintln(
      ga,
      stdout);

  }

  GradAutomatonWolframOriginalFree(&ga);
```

```
  printf("UnitTestGradAutomatonWolframOriginalStepPrintln OK\n");

}

void UnitTestGradAutomatonWolframOriginalLoadSave(void) {

  unsigned char rule = 30;
  long size = 100;
  GradAutomatonWolframOriginal* ga =
    GradAutomatonCreateWolframOriginal(
      rule,
      size);

  FILE* fp =
    fopen(
      "./unitTestGradAutomatonWolframOriginalSave.json",
      "w");
  bool compact = false;
  bool ret =
    GradAutomatonSave(
      ga,
      fp,
      compact);
  if (ret == false) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonWolframOriginalSave failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonWolframOriginalFree(&ga);
  fclose(fp);
  fp =
    fopen(
      "./unitTestGradAutomatonWolframOriginalSave.json",
      "r");

  ret =
    GradAutomatonLoad(
      &ga,
      fp);

  if (
    ret == false ||
    GrAFunWolframOriginalGetRule(GradAutomatonFun(ga)) != rule) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonWolframOriginalLoad failed");
    PBErrCatch(GradAutomatonErr);

  }

  const VecShort2D* dim = GradDim(GradAutomatonGrad(ga));
  long sizeLoaded =
    VecGet(
      dim,
      0);
```

```
  if (sizeLoaded != size) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonWolframOriginalLoad failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonWolframOriginalFree(&ga);
  fclose(fp);

  printf("UnitTestGradAutomatonWolframOriginalLoadSave OK\n");

}

void UnitTestGradAutomatonWolframOriginal(void) {

  UnitTestGradAutomatonWolframOriginalCreateFree();
  UnitTestGradAutomatonWolframOriginalGet();
  UnitTestGradAutomatonWolframOriginalStepPrintln();
  UnitTestGradAutomatonWolframOriginalLoadSave();
  printf("UnitTestGradAutomatonWolframOriginal OK\n");

}

void UnitTestGradAutomatonNeuraNetCreateFree(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  long nbHiddenLayers = 1;
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nbHiddenLayers);
  if (
    ga == NULL ||
    ga->gradAutomaton.grad == NULL ||
    ga->gradAutomaton.fun == NULL ||
    ga->gradAutomaton.type != GradAutomatonTypeNeuraNet ||
    ga->gradAutomaton.isStable != false ||
    ga->gradAutomaton.grad->_type != GradTypeSquare ||
    ga->gradAutomaton.grad->_dim._val[0] != 2 ||
    ga->gradAutomaton.grad->_dim._val[1] != 2) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonCreateNeuraNetSquare failed");
    PBErrCatch(GradAutomatonErr);
```

```
  }

  GradAutomatonNeuraNetFree(&ga);
  if (ga != NULL) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetFree failed");
    PBErrCatch(GradAutomatonErr);

  }

  printf("UnitTestGradAutomatonNeuraNetCreateFree OK\n");

}

void UnitTestGradAutomatonNeuraNetGet(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  long nbHiddenLayers = 1;
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nbHiddenLayers);
  if (GradAutomatonGrad(ga) != ga->gradAutomaton.grad) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetGrad failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (GradAutomatonIsStable(ga) != ga->gradAutomaton.isStable) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetIsStable failed");
    PBErrCatch(GradAutomatonErr);

  }

  if (GradAutomatonNeuraNetGetGradType(ga) != GradTypeSquare) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
```

```
    GradAutomatonErr->_msg,
    "GradAutomatonNeuraNetGradType failed");
  PBErrCatch(GradAutomatonErr);

}

if ((void*)GradAutomatonFun(ga) != ga->gradAutomaton.fun) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonNeuraNetFun failed");
  PBErrCatch(GradAutomatonErr);

}

for (
  long i = 0;
  i < 4;
  ++i) {

  void* cellA =
    GradAutomatonCell(
      ga,
      i);
  void* cellB =
    GradCellAt(
      ga->gradAutomaton.grad,
      i);
  if (cellA != GradCellData(cellB)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetCellIndex failed");
    PBErrCatch(GradAutomatonErr);

  }

}

VecShort2D pos = VecShortCreateStatic2D(2);
bool flag = true;
do {

  void* cellA =
    GradAutomatonCell(
      ga,
      &pos);
  void* cellB =
    GradCellAt(
      ga->gradAutomaton.grad,
      &pos);
  if (cellA != GradCellData(cellB)) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetCellPos failed");
    PBErrCatch(GradAutomatonErr);

  }
```

```
    flag =
      VecStep(
        &pos,
        &dimGrad);

  } while(flag);

  GradAutomatonNeuraNetFree(&ga);

  printf("UnitTestGradAutomatonNeuraNetGet OK\n");

}

void UnitTestGradAutomatonNeuraNetStep(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  long nbHiddenLayers = 1;
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nbHiddenLayers);

  for (
    long iStep = 0;
    iStep < 2;
    ++iStep) {

    GradAutomatonStep(ga);

  }

  GradAutomatonNeuraNetFree(&ga);

  printf("UnitTestGradAutomatonNeuraNetStep OK\n");

}

void UnitTestGradAutomatonNeuraNetSquareLoadSave(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
```

```
bool diagLink = false;
long nbHiddenLayers = 1;
GradAutomatonNeuraNet* ga =
  GradAutomatonCreateNeuraNetSquare(
    dimStatus,
    &dimGrad,
    diagLink,
    nbHiddenLayers);

FILE* fp =
  fopen(
    "./unitTestGradAutomatonNeuraNetSquareSave.json",
    "w");
bool compact = false;
bool ret =
  GradAutomatonSave(
    ga,
    fp,
    compact);
if (ret == false) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonNeuraNetSave failed");
  PBErrCatch(GradAutomatonErr);

}

GradAutomatonNeuraNetFree(&ga);
fclose(fp);
fp =
  fopen(
    "./unitTestGradAutomatonNeuraNetSquareSave.json",
    "r");

ret =
  GradAutomatonLoad(
    &ga,
    fp);

if (
  ret == false) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
    "GradAutomatonNeuraNetLoad failed");
  PBErrCatch(GradAutomatonErr);

}

const VecShort2D* dim = GradDim(GradAutomatonGrad(ga));
bool sameSize =
  VecIsEqual(
    &dimGrad,
    dim);
if (sameSize == false) {

  GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
  sprintf(
    GradAutomatonErr->_msg,
```

```
      "GradAutomatonNeuraNetLoad failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonNeuraNetFree(&ga);
  fclose(fp);

  printf("UnitTestGradAutomatonNeuraNetSquareLoadSave OK\n");

}

void UnitTestGradAutomatonNeuraNetHexaLoadSave(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  long nbHiddenLayers = 1;
  GradHexaType hexaType = GradHexaTypeOddQ;
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetHexa(
      dimStatus,
      &dimGrad,
      hexaType,
      nbHiddenLayers);

  FILE* fp =
    fopen(
      "./unitTestGradAutomatonNeuraNetHexaSave.json",
      "w");
  bool compact = false;
  bool ret =
    GradAutomatonSave(
      ga,
      fp,
      compact);
  if (ret == false) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetSave failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonNeuraNetFree(&ga);
  fclose(fp);
  fp =
    fopen(
      "./unitTestGradAutomatonNeuraNetHexaSave.json",
      "r");

  ret =
    GradAutomatonLoad(
```

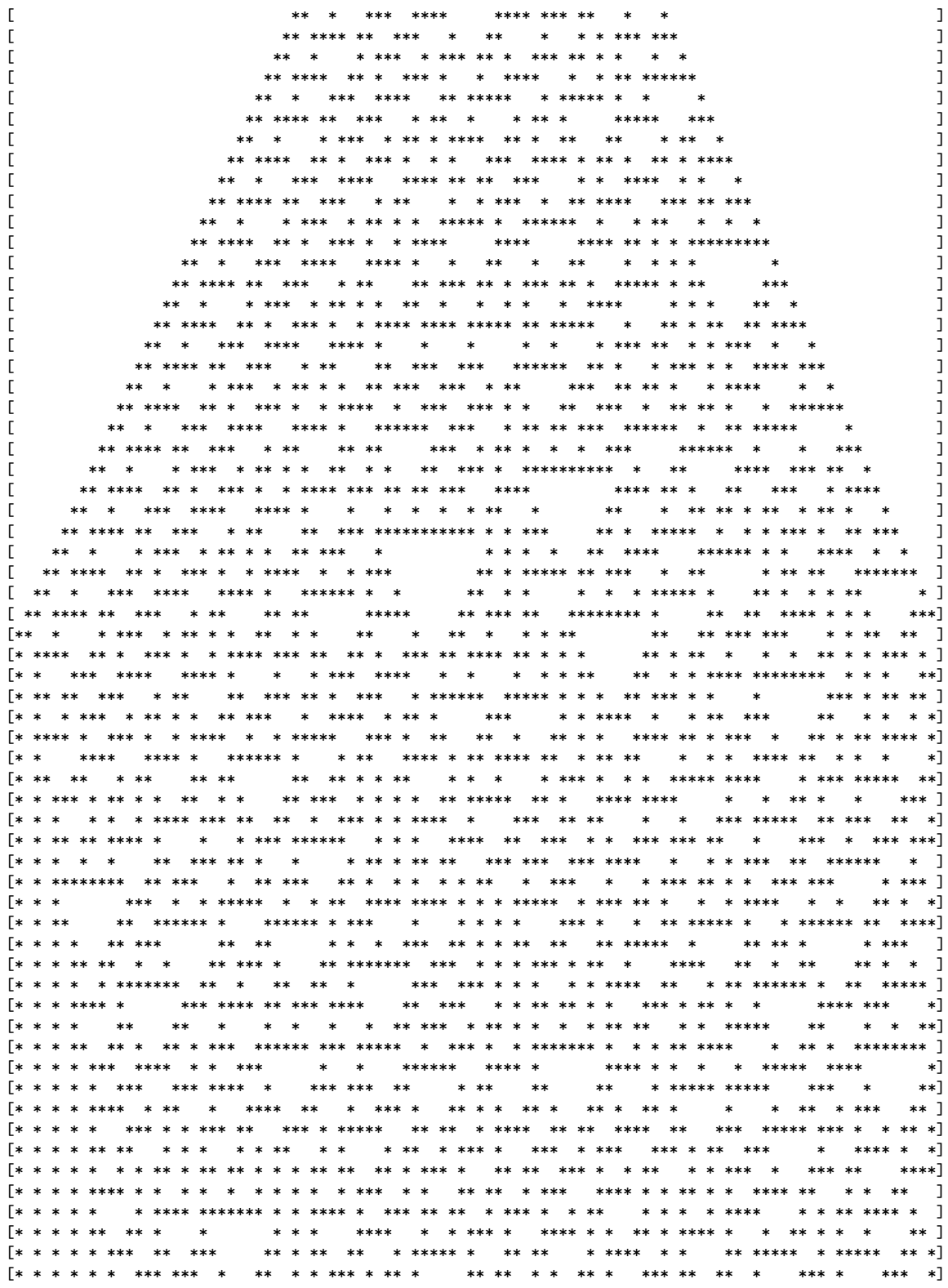
```
      &ga,
      fp);

  if (
    ret == false) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetLoad failed");
    PBErrCatch(GradAutomatonErr);

  }

  const VecShort2D* dim = GradDim(GradAutomatonGrad(ga));
  bool sameSize =
    VecIsEqual(
      &dimGrad,
      dim);
  if (sameSize == false) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetLoad failed");
    PBErrCatch(GradAutomatonErr);

  }

  GradAutomatonNeuraNetFree(&ga);
  fclose(fp);

  printf("UnitTestGradAutomatonNeuraNetHexaLoadSave OK\n");

}

void UnitTestGradAutomatonNeuraNet(void) {

  UnitTestGradAutomatonNeuraNetCreateFree();
  UnitTestGradAutomatonNeuraNetGet();
  UnitTestGradAutomatonNeuraNetStep();
  UnitTestGradAutomatonNeuraNetSquareLoadSave();
  UnitTestGradAutomatonNeuraNetHexaLoadSave();
  printf("UnitTestGradAutomatonNeuraNet OK\n");

}

void UnitTestGradAutomaton(void) {

  UnitTestGradAutomatonDummy();
  UnitTestGradAutomatonWolframOriginal();
  UnitTestGradAutomatonNeuraNet();
  printf("UnitTestGradAutomaton OK\n");

}

void UnitTestAll(void) {

  UnitTestGrACell();
  UnitTestGrAFun();
  UnitTestGradAutomaton();
  printf("UnitTestAll OK\n");
```

```
}

int main(void) {

  UnitTestAll();

  // Return success code
  return 0;

}
```

6 Unit tests output

unitTestRef.txt:

```
UnitTestGrACellCreateFree OK
UnitTestGrACellSwitchStatus OK
UnitTestGrACellCurPrevStatus OK
UnitTestGrACellCurGetSet OK
UnitTestGrACell OK
UnitTestGrAFunDummyCreateFree OK
UnitTestGrAFunDummyGetType OK
UnitTestGrAFunDummy OK
UnitTestGrAFunWolframOriginalCreateFree OK
UnitTestGrAFunWolframOriginalGetType OK
UnitTestGrAFunWolframOriginalGetRule OK
UnitTestGrAFunWolframOriginal OK
UnitTestGrAFunNeuraNetCreateFree OK
UnitTestGrAFunNeuraNetGetType OK
UnitTestGrAFunNeuraNetNN OK
UnitTestGrAFunNeuraNet OK
UnitTestGrAFun OK
UnitTestGradAutomatonDummyCreateFree OK
UnitTestGradAutomatonDummyGet OK
UnitTestGradAutomatonDummyStep OK
UnitTestGradAutomatonDummy OK
UnitTestGradAutomatonWolframOriginalCreateFree OK
UnitTestGradAutomatonWolframOriginalGet OK
[                                                 *                                  ]
[                                                ***                                 ]
[                                               **  *                                ]
[                                              ** ****                               ]
[                                             **  *   *                              ]
[                                            ** **** ***                             ]
[                                           **  *    *  *                            ]
[                                          ** ****  ******                           ]
[                                         **  *   ***     *                          ]
[                                        ** **** **  *   ***                         ]
[                                       **  *    * **** **  *                        ]
[                                      ** ****  ** *    * ****                       ]
[                                     **  *   ***  **  ** *   *                      ]
[                                    ** **** **  *** ***  ** ***                     ]
[                                   **  *    * ***   *  ***  *  *                    ]
[                                  ** ****  ** *  * *****  *******                  ]
[                                 **  *   ***  **** *    ***      *                 ]
[                                ** **** **  ***    **  **  *    ***                ]
[                               **  *    * ***  *  ** *** ****  **  *               ]
[                              ** ****  ** *  ******  *   *   *** ****              ]
```



```
[* * * * * ****   *  **** ** *** * *   * *  **   **  * *** ****  ** **   * *** ****  **   **  **  ***]
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[* * * * * * * *        *  *     * *** * **** *  ** **  *  * **   *** **      * * *** * *** *  *  * *]
[* * * * * * * **      ******   ** *   * *    ****  * ****** * * **   * *    ** * *   * *   ******* *]
UnitTestGradAutomatonWolframOriginalStepPrintln OK
UnitTestGradAutomatonWolframOriginalLoadSave OK
UnitTestGradAutomatonWolframOriginal OK
UnitTestGradAutomatonNeuraNetCreateFree OK
UnitTestGradAutomatonNeuraNetGet OK
UnitTestGradAutomatonNeuraNetStep OK
UnitTestGradAutomatonNeuraNetSquareLoadSave OK
UnitTestGradAutomatonNeuraNetHexaLoadSave OK
UnitTestGradAutomatonNeuraNet OK
UnitTestGradAutomaton OK
UnitTestAll OK
```

unitTestGradAutomatonWolframOriginalSave.json

```
{
  "rule":"30",
  "size":"100"
}
```

unitTestGradAutomatonNeuraNetSquareSave.json

```
{
  "typeGrad":"0",
  "dimGrad":{
    "_dim":"2",
    "_val":["2","2"]
  },
  "dimStatus":"3",
  "nbHiddenLayers":"1",
  "diagLink":"0",
  "nn":{
    "_nbInputVal":"15",
    "_nbOutputVal":"3",
    "_nbMaxHidVal":"15",
    "_nbMaxBases":"270",
    "_nbMaxLinks":"270",
    "_bases":{
      "_dim":"810",
      "_val":["0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.0
    },
    "_links":{
      "_dim":"810",
      "_val":["0","0","15","1","0","16","2","0","17","3","0","18","4","0","19","5","0","20","6","0","21","7","0","22
```

```
    }
  }
}
```


unitTestGradAutomatonNeuraNetHexaSave.json


```
{
  "typeGrad":"1",
  "dimGrad":{
    "_dim":"2",
    "_val":["2","2"]
  },
  "dimStatus":"3",
  "nbHiddenLayers":"1",
  "typeGradHexa":"2",
  "nn":{
    "_nbInputVal":"18",
    "_nbOutputVal":"3",
    "_nbMaxHidVal":"18",
    "_nbMaxBases":"378",
    "_nbMaxLinks":"378",
    "_bases":{
      "_dim":"1134",
      "_val":["0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.000000","0.0
    },
    "_links":{
      "_dim":"1134",
      "_val":["0","0","18","1","0","19","2","0","20","3","0","21","4","0","22","5","0","23","6","0","24","7","0","25"
    }
  }
}
```