

# GradAutomaton

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## 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
GrACell* _GrACellShortGradCell(const GrACellShort* const that);

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

// Return the GrACellShort 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);

```

```

// ----- GradAutomatonWolframOriginal

// ===== 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 GradAutomatonWolframOriginal '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 GradAutomatonWolframOriginal '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) {

#ifdef 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) {

#ifdef 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) {

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

        GradAutomatonErr->_type = PErrTypeNullPointer;
        sprintf(
            GradAutomatonErr->_msg,
            "'that' is null");
        PErrCatch(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
        GrCell* cell =
            GradAutomatonCell(
                that,
                iCell);

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

    }

}

// ----- GradAutomatonDummy

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

    // Allocate memory for the new GradAutomatonDummy
    GradAutomatonDummy* that =
        PErrMalloc(
            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);

    GradCellShort* 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 = PErrTypeNullPointer;
            sprintf(
                GradAutomatonErr->_msg,
                "'that' is null");
            PErrCatch(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 =
        PErrMalloc(
            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 the 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);

        GradCellShort* 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) {

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

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

    }

#endif
}

```

```

#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) {

#ifdef 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 = PErrTypeNullPointer;
            sprintf(
                GradAutomatonErr->_msg,
                "'that' is null");
            PErrCatch(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) {

#ifdef 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 GradAutomatonWolframOriginal '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 = PErrTypeNullPointer;
            sprintf(
                GradAutomatonErr->_msg,
                "'that' is null");
            PErrCatch(GradAutomatonErr);

        }

        if (stream == NULL) {

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

    GradCellFloat* 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) {

#ifdef 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) {

#ifdef 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) {
#ifdef 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) {

#ifdef 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 GradAutomatonWolframOriginal '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) {

#ifdef 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

```

```

#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 = PErrTypeNullPointer;
        sprintf(
            GradAutomatonErr->_msg,
            "'that' is null");
        PErrCatch(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 = PErrTypeNullPointer;
        sprintf(
            GradAutomatonErr->_msg,
            "'that' is null");
        PErrCatch(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) {

#ifdef 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'
#ifdef BUILDMODE != 0
static inline
#endif
void _GrACellFloatSetCurStatus(
    const GrACellFloat* const that,
    const unsigned long iVal,
    const float val) {

#ifdef 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'
#ifdef BUILDMODE != 0
static inline
#endif
GradCell* _GrACellShortGradCell(const GrACellShort* const that) {

#ifdef 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 GrCellShort at position 'pos' for the
// GradAutomatonDummy 'that'
#if BUILDMODE != 0
static inline
#endif
GrCellShort* _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 GrCellShort associated to the cell
    return (GrCellShort*)GradCellData(cell);

}

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

```

```

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

#ifdef 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'
#ifdef BUILDMODE != 0
static inline
#endif
GradSquare* _GradAutomatonWolframOriginalGrad(
    const GradAutomatonWolframOriginal* const that) {

#ifdef 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'
#ifdef BUILDMODE != 0
static inline
#endif
GrAFunWolframOriginal* _GradAutomatonWolframOriginalFun(

```

```

    const GradAutomatonWolframOriginal* const that) {

#ifdef 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'
#ifdef BUILDMODE != 0
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellPos(
    GradAutomatonWolframOriginal* const that,
    const VecShort2D* const pos) {

#ifdef 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");
    PBErriCatch(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 = PBErriTypeUnitTestFailed;
        sprintf(
            GradAutomatonErr->_msg,
            "GrAFunNeuraNetGetType failed");
        PBErriCatch(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 = PBErriTypeUnitTestFailed;
        sprintf(
            GradAutomatonErr->_msg,

```

```

        "GrAFunNeuraNetNN failed");
        PBErriCatch(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 = PBErriTypeUnitTestFailed;
        sprintf(
            GradAutomatonErr->_msg,
            "GradAutomatonCreateDummy failed");
        PBErriCatch(GradAutomatonErr);
    }

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

        GradAutomatonErr->_type = PBErriTypeUnitTestFailed;
        sprintf(
            GradAutomatonErr->_msg,
            "GradAutomatonDummyFree failed");
        PBErriCatch(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");
    PBErCatch(GradAutomatonErr);
}

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

    GradAutomatonErr->_type = PBErTypeUnitTestFailed;
    sprintf(
        GradAutomatonErr->_msg,
        "GradAutomatonWolframOriginalFun failed");
    PBErCatch(GradAutomatonErr);
}

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

    GradAutomatonErr->_type = PBErTypeUnitTestFailed;
    sprintf(
        GradAutomatonErr->_msg,
        "GradAutomatonWolframOriginalIsStable failed");
    PBErCatch(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 = PBErTypeUnitTestFailed;
        sprintf(
            GradAutomatonErr->_msg,
            "GradAutomatonWolframOriginalCellIndex failed");
        PBErCatch(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:

[illegible]

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