GradAutomaton

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Contents

Introduction

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

It currently implements the following cellular automaton:

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

It uses the `PBErr`, `Grad`, `NeuraNet` 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 "neuranet.h"

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

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

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

typedef struct GrACell {

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

  // Pointer toward the supporting GradCell
  GradCell* gradCell;

} GrACell;

typedef struct GrACellShort {

  // Parent GrACell
  GrACell gradAutomatonCell;

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

} GrACellShort;

typedef struct GrACellFloat {

  // Parent GrACell
  GrACell gradAutomatonCell;

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

} GrACellFloat;

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

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

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

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

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

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

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

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

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

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

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

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

// Return the 'iVal'-th value of the previous status of the
```

```
// GrACellFloat 'that'
#if BUILDMODE != 0
static inline
#endif
float _GrACellFloatGetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal);

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

typedef enum GrAFunType {

  GrAFunTypeDummy,
  GrAFunTypeWolframOriginal,
  GrAFunTypeNeuraNet

} GrAFunType;

typedef struct GrAFun {

  // Type of GrAFun
  GrAFunType type;

} GrAFun;

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

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

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

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

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

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

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

typedef struct GrAFunDummy {

  // GrAFun
  GrAFun grAFun;

} GrAFunDummy;

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

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

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

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

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

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

typedef struct GrAFunWolframOriginal {

  // GrAFun
  GrAFun grAFun;

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

} GrAFunWolframOriginal;

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

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

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

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

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

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

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

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

typedef struct GrAFunNeuraNet {

  // GrAFun
  GrAFun grAFun;

  // NeuraNet applied to the cells
  NeuraNet* nn;

} GrAFunNeuraNet;

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

```
// Create a new GrAFunNeuraNet
GrAFunNeuraNet* GrAFunCreateNeuraNet(
  NeuraNet* const nn);

// 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 dim;

  // Grad
  Grad* grad;

  // GrAFun
  GrAFun* fun;

} GradAutomaton;

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

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

// 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);

// -------------- 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 static GradAutomaton
GradAutomaton GradAutomatonCreateStatic(
  const GradAutomatonType type,
              Grad* const grad,
            GrAFun* const fun);

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

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

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

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

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

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

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

// -------------- GradAutomatonWorlframOriginal

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

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

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

  // Parent GradAutomaton
  GradAutomaton gradAutomaton;

} GradAutomatonWolframOriginal;
```

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

  // Parent GradAutomaton
  GradAutomaton gradAutomaton;

} GradAutomatonNeuraNet;

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

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

// Create a new GradAutomatonNeuraNet with a GradHexa
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetHexa(
               const long dimStatus,
  const VecShort2D* const dimGrad,
       const GradHexaType gradType,
          NeuraNet* const nn);

// 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);

// ================= 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, \
  default: PBErrInvalidPolymorphism)(G)

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

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

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

```
    _GradAutomatonWolframOriginalLoad, \
  const GradAutomatonWolframOriginal** :\
    _GradAutomatonWolframOriginalLoad, \
  default: PBErrInvalidPolymorphism)(G, S)

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

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

#endif
```

3 Code

3.1 gradautomaton.c

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

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

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

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

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

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

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

  // Create the new GradAutomatonCell
  GrACell cell;

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

  // Return the new GradAutomatonCell
  return cell;

}

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

  // Allocate memory
  GrACellShort* that =
    PBErrMalloc(
      GradAutomatonErr,
```

```
      sizeof(GrACellShort));

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

  // Return the new GrACellShort
  return that;

}

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

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

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

  // Return the new GrACellFloat
  return that;

}

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

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

    // Do nothing
    return;

  }

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

}

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

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

    // Do nothing
    return;
```

```
  }

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

}

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

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

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

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

  // Declare the new GrAFun
  GrAFun that;

  // Set properties
  that.type = type;

  // Return the new GrAFun
  return that;

}

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

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

    // Do nothing
    return;

  }

}

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

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

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

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

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

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

  // Return the new GrAFun
```

```
  return that;

}

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

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

    // Do nothing
    return;

  }

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

}

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

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

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

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

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

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

  // Return the new GrAFun
  return that;

}

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

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

    // Do nothing
    return;

  }

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

```
}

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

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

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

  }

  if (grad == NULL) {

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

  }

  if (cell == NULL) {

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

  }

#endif

  // Declare a variable to memorize the current status of the
  // cell and its neighbour
  short status[3] = {0, 0, 0};

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

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

```
      VecGet(
        GrACellCurStatus(leftCell),
        0);

  }

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

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

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

  }

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

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

    newStatus = 1;

  }

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

}

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

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

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

```
// Create a new GrAFunNeuraNet
GrAFunNeuraNet* GrAFunCreateNeuraNet(
  NeuraNet* const nn) {

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

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

  // Return the new GrAFun
  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
  _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) {

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

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

  }

  if (fun == NULL) {

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

  }

#endif

  // Declare the new GradAutomaton
  GradAutomaton that;

  // Set the properties
  that.type = type;
  that.grad = grad;
  that.fun = fun;

  // Return the new GradAutomaton
  return that;

}

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

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

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

  }

#endif

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

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

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

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

  }

}

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

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

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

  // Create the associated Grad and GrAFun
  bool diagLink = false;
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(
    &dim,
    0,
    2);
  VecSet(
    &dim,
    1,
    2);
  Grad* grad =
    (Grad*)GradSquareCreate(
      &dim,
      diagLink);
  GrAFun* fun = (GrAFun*)GrAFunCreateDummy();

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

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

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

    long dimStatus = 1;
    GrACellShort* cellStatus =
      GrACellCreateShort(
```

```
        dimStatus,
        cell);

    GradCellSetData(
      cell,
      cellStatus);

    flag =
      VecStep(
        &pos,
        &dim);

  } while(flag);

  // Return the new GradAutomatonDummy
  return that;

}

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

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

    // Do nothing
    return;

  }

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

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

    GrACellShort* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

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

  } while(flag);

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

}

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

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

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

  }

#endif

  (void)that;

}

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

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

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

  // Create the associated Grad and GrAFun
  bool diagLink = false;
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(
    &dim,
    0,
    size);
  VecSet(
    &dim,
    1,
    1);
  Grad* grad =
    (Grad*)GradSquareCreate(
      &dim,
      diagLink);
  GrAFun* fun = (GrAFun*)GrAFunCreateWolframOriginal(rule);

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

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

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

```
    GradCell* cell =
      GradCellAt(
        grad,
        iCell);

    long dimStatus = 1;
    GrACellShort* cellStatus =
      GrACellCreateShort(
        dimStatus,
        cell);

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

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

    }

    GradCellSetData(
      cell,
      cellStatus);

  };

  // Return the new GradAutomatonWolframOriginal
  return that;

}

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

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

    // Do nothing
    return;

  }

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

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

    GradCell* cell =
      GradCellAt(
        GradAutomatonGrad(*that),
```

```
        iCell);

    GrACellShort* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

  }

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

}

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

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

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

  }

#endif

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

  // 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);

  }

  // Switch all the cells
  GradAutomatonSwitchAllStatus(that);

}

// Print the GradAutomatonWolframOriginal 'that' on the FILE 'stream'
```

```
void _GradAutomatonWolframOriginalPrintln(
  GradAutomatonWolframOriginal* const that,
                                FILE* stream) {

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

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

  }

  if (stream == NULL) {

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

  }

#endif

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

  fprintf(
    stream,
    "[");

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

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

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

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

      fprintf(
        stream,
        " ");

    } else {

      fprintf(
```

```
        stream,
        "*");

    }

  }

  fprintf(
    stream,
    "]\n");

}

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

#if BUILDMODE == 0

  if (that == NULL) {

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

  }

#endif

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

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

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

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

```
    val);

  // Return the created JSON
  return json;

}

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

#if BUILDMODE == 0

  if (that == NULL) {

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

  }

  if (json == NULL) {

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

  }

#endif

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

    // Free memory
    GradAutomatonWolframOriginalFree(that);

  }

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

    return false;

  }

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

  // Decode the size
  prop =
    JSONProperty(
      json,
      "size");
```

```
  if (prop == NULL) {

    return false;

  }

  long size = atol(JSONLblVal(prop));

  // Create the GradAutomatonWolframOriginal
  *that =
    GradAutomatonCreateWolframOriginal(
      rule,
      size);

  // Return the success code
  return true;

}

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

#if BUILDMODE == 0

  if (that == NULL) {

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

  }

  if (stream == NULL) {

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

  }

#endif

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

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

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

  // Return success code
  return ret;

}

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

#if BUILDMODE == 0

  if (that == NULL) {

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

  }

  if (stream == NULL) {

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

  }

#endif

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

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

  if (ret == true) {

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

  }

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

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

}

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

// Create a new GradAutomatonNeuraNet with a GradSquare
GradAutomatonNeuraNet* GradAutomatonCreateNeuraNetSquare(
               const long dimStatus,
  const VecShort2D* const dimGrad,
               const bool diagLink,
         NeuraNet* const nn) {

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

  // Create the associated Grad and GrAFun
  Grad* grad =
    (Grad*)GradSquareCreate(
      dimGrad,
      diagLink);
  GrAFun* fun = (GrAFun*)GrAFunCreateNeuraNet(nn);

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

  // 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);

  }

  // 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,
          NeuraNet* const nn) {

  // 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;

  }

  GrAFun* fun = (GrAFun*)GrAFunCreateNeuraNet(nn);

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

  // 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);

  }

  // Return the new GradAutomatonNeuraNet
  return that;

}

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

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

    // Do nothing
    return;

  }

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

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

    GrACellFloat* cellStatus = GradCellData(cell);

    GrACellFree(&cellStatus);

  }

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

}

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

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

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

  }
```

```
#endif

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

  // 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);

  }

  // Switch all the cells
  GradAutomatonSwitchAllStatus(that);

}
```

3.2 gradautomaton-inline.c

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

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

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

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

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

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

  }

#endif

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

}
```

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

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

}

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

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

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

```
  }

#endif

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

}

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

  return VecGet(
    GrACellPrevStatus(that),
    iVal);

}

// Return the 'iVal'-th value of the previous status of the
// GrACellFloat 'that'
#if BUILDMODE != 0
```

```
static inline
#endif
float _GrACellFloatGetPrevStatus(
  const GrACellFloat* const that,
        const unsigned long iVal) {

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

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

  }

#endif

  return VecGet(
    GrACellPrevStatus(that),
    iVal);

}

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

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

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

  }

#endif

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

}

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

```
        const unsigned long iVal,
                const float val) {

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

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

  }

#endif

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

}

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

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

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

  }

#endif

  return VecGet(
    GrACellCurStatus(that),
    iVal);

}

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

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

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

  }

#endif

  return VecGet(
    GrACellCurStatus(that),
    iVal);

}

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

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

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

  }

#endif

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

}

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

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

  return that->gradAutomatonCell.gradCell;

}

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

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

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

  }

#endif

  return that->gradAutomatonCell.gradCell;

}

// -------------- GrAFun
```

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

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

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

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

  }

#endif

  return that->type;

}

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

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

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

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

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

  }

#endif

  return that->rule;

}

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

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

// Return the NeuraNet of the GrAFunNeuraNet 'that'
#if BUILDMODE != 0
static inline
#endif
```

```
NeuraNet* GrAFunNeuraNetNN(
  GrAFunNeuraNet* const that) {

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

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

  }

#endif

  return that->nn;

}

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

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

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

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

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

  }

#endif

  // Return the Grad
  return that->grad;

}

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

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

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

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

  }

  if (pos == NULL) {

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

  }

#endif

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

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

}

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

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

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

  }

#endif

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

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

}

// -------------- GradAutomatonDummy
```

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

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

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

}

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

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

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

  }

  if (pos == NULL) {

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

  }

#endif

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

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

}

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

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

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

  }

#endif

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

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

}

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

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

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

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

}

// Return the GrACellShort at position 'pos' for the
// GradAutomatonWolframOriginal 'that'
#if BUILDMODE != 0
```

```
static inline
#endif
GrACellShort* _GradAutomatonWolframOriginalCellPos(
  GradAutomatonWolframOriginal* const that,
              const VecShort2D* const pos) {

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

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

  }

  if (pos == NULL) {

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

  }

#endif

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

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

}

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

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

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

  }

#endif
```

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

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

}

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

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

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

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

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

  }

#endif

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

}

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

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

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

  }

#endif

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

```
}

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

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

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

  }

#endif

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

}

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

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

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

  }

  if (pos == NULL) {

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

  }

#endif

  // Get the GradCell at the requested position
  GradCell* cell =
```

```
    GradCellAt(
      GradAutomatonGrad(that),
      pos);

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

}

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

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

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

  }

#endif

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

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

}
```

4 Makefile

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

all: 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);
  NeuraNet* nn =
    NeuraNetCreateFullyConnected(
      nbIn,
      nbOut,
      hiddenLayers);
  GrAFunNeuraNet* fun = GrAFunCreateNeuraNet(nn);
  if (
    fun == NULL ||
    fun->grAFun.type != GrAFunTypeNeuraNet ||
    fun->nn != nn) {
```

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

  }

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

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

  }

  NeuraNetFree(&nn);
  VecFree(&hiddenLayers);

  printf("UnitTestGrAFunNeuraNetCreateFree OK\n");

}

void UnitTestGrAFunNeuraNetGetType(void) {

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

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

  }

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

  printf("UnitTestGrAFunNeuraNetGetType OK\n");

}

void UnitTestGrAFunNeuraNetNN(void) {
```

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

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

  }

  GrAFunFree(&fun);
  NeuraNetFree(&nn);
  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) {

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

```
    PBErrCatch(GradAutomatonErr);

  }

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

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

  }

  printf("UnitTestGradAutomatonDummyCreateFree OK\n");

}

void UnitTestGradAutomatonDummyGet(void) {

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

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

  }

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

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

  }

  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);

  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 ||
    ((GrAFunWolframOriginal*)(ga->gradAutomaton.fun))->rule != rule ||
    ga->gradAutomaton.grad->_dim._val[0] != size ||
    ga->gradAutomaton.grad->_dim._val[1] != 1) {

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

  }

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

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

  }

  printf("UnitTestGradAutomatonWolframOriginalCreateFree OK\n");

}

void UnitTestGradAutomatonWolframOriginalGet(void) {

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

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

```
  PBErrCatch(GradAutomatonErr);

}

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

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

}

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

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

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

  }

}

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

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

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

    }

    flag =
      VecStep(
        &pos,
        &dim);

  } while(flag);

  GradAutomatonWolframOriginalFree(&ga);

  printf("UnitTestGradAutomatonWolframOriginalGet OK\n");

}

void UnitTestGradAutomatonWolframOriginalStepPrintln(void) {

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

  GradAutomatonPrintln(
    ga,
    stdout);

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

    GradAutomatonStep(ga);

    GradAutomatonPrintln(
      ga,
      stdout);

  }

  GradAutomatonWolframOriginalFree(&ga);

  printf("UnitTestGradAutomatonWolframOriginalStepPrintln OK\n");

}

void UnitTestGradAutomatonWolframOriginalLoadSave(void) {

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

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

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

}

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

ret =
  GradAutomatonLoad(
    &ga,
    fp);

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

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

}

const VecShort2D* dim = GradDim(GradAutomatonGrad(ga));
long sizeLoaded =
  VecGet(
    dim,
    0);
if (sizeLoaded != size) {

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

}

GradAutomatonWolframOriginalFree(&ga);
fclose(fp);
```

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

}

void UnitTestGradAutomatonWolframOriginal(void) {

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

}

void UnitTestGradAutomatonNeuraNetCreateFree(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  int nbIn = dimStatus * 9;
  int nbOut = dimStatus;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  NeuraNet* nn =
    NeuraNetCreateFullyConnected(
      nbIn,
      nbOut,
      hiddenLayers);
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nn);
  if (
    ga == NULL ||
    ga->gradAutomaton.grad == NULL ||
    ga->gradAutomaton.fun == NULL ||
    ga->gradAutomaton.type != GradAutomatonTypeNeuraNet ||
    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);

  }

  NeuraNetFree(&nn);
  VecFree(&hiddenLayers);

  printf("UnitTestGradAutomatonNeuraNetCreateFree OK\n");

}

void UnitTestGradAutomatonNeuraNetGet(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  int nbIn = dimStatus * 9;
  int nbOut = dimStatus;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  NeuraNet* nn =
    NeuraNetCreateFullyConnected(
      nbIn,
      nbOut,
      hiddenLayers);
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nn);
  if (GradAutomatonGrad(ga) != ga->gradAutomaton.grad) {

    GradAutomatonErr->_type = PBErrTypeUnitTestFailed;
    sprintf(
      GradAutomatonErr->_msg,
      "GradAutomatonNeuraNetGrad 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);
  NeuraNetFree(&nn);
  VecFree(&hiddenLayers);

  printf("UnitTestGradAutomatonNeuraNetGet OK\n");

}

void UnitTestGradAutomatonNeuraNetStep(void) {

  long dimStatus = 3;
  VecShort2D dimGrad = VecShortCreateStatic2D();
  VecSet(
    &dimGrad,
    0,
    2);
  VecSet(
    &dimGrad,
    1,
    2);
  bool diagLink = true;
  int nbIn = dimStatus * 9;
  int nbOut = dimStatus;
  VecLong* hiddenLayers = VecLongCreate(1);
  VecSet(
    hiddenLayers,
    0,
    1);
  NeuraNet* nn =
    NeuraNetCreateFullyConnected(
      nbIn,
      nbOut,
      hiddenLayers);
  GradAutomatonNeuraNet* ga =
    GradAutomatonCreateNeuraNetSquare(
      dimStatus,
      &dimGrad,
      diagLink,
      nn);

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

    GradAutomatonStep(ga);

  }

  GradAutomatonNeuraNetFree(&ga);
  NeuraNetFree(&nn);
  VecFree(&hiddenLayers);
```

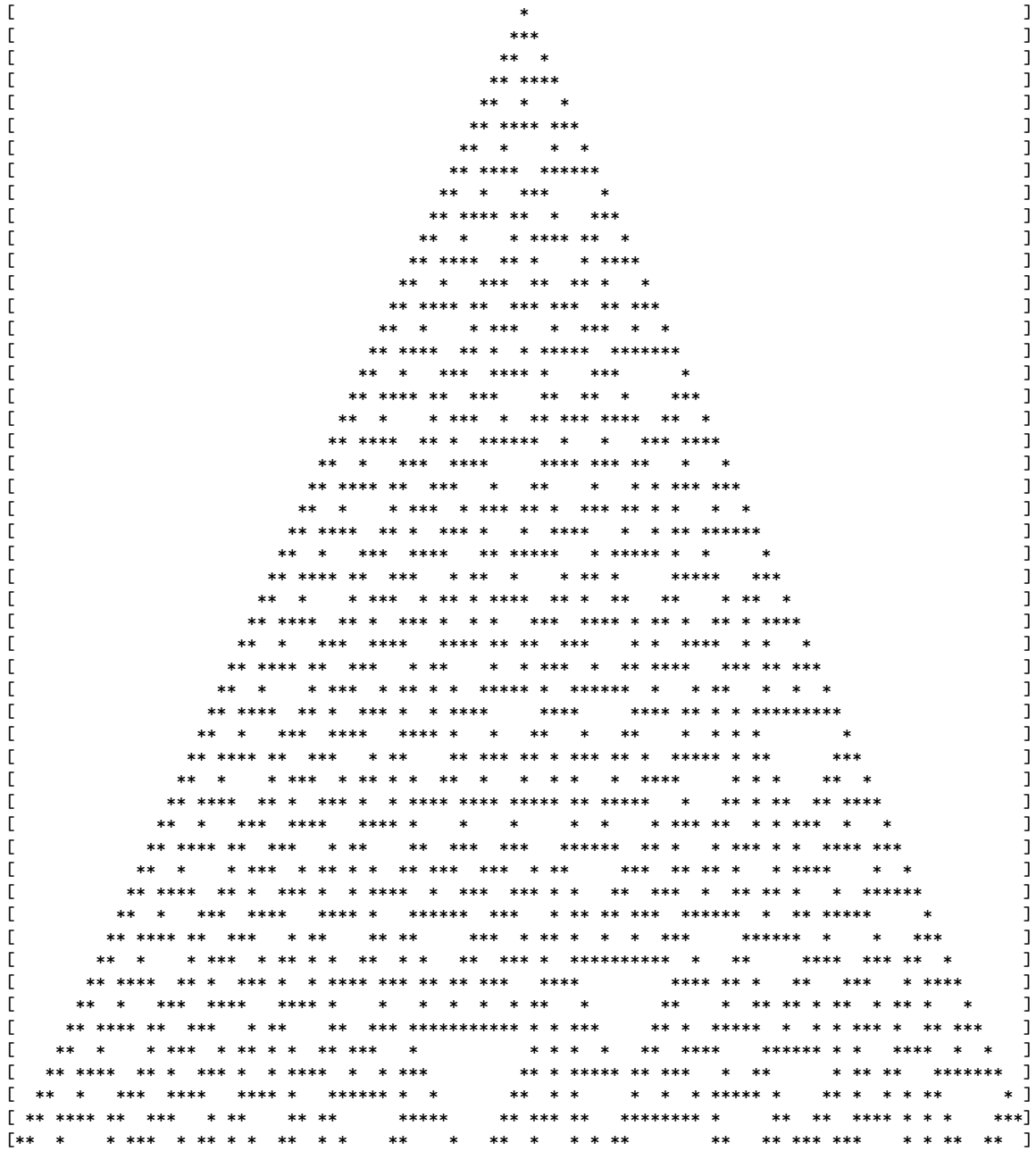
```
  printf("UnitTestGradAutomatonNeuraNetStep OK\n");

}

void UnitTestGradAutomatonNeuraNet(void) {

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

}

void UnitTestGradAutomaton(void) {

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

}

void UnitTestAll(void) {

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

}

int main(void) {

  UnitTestAll();

  // Return success code
  return 0;

}
```

6 Unit tests output

unitTestRef.txt:

```
UnitTestGrACellCreateFree OK
UnitTestGrACellSwitchStatus OK
UnitTestGrACellCurPrevStatus OK
UnitTestGrACellCurGetSet OK
UnitTestGrACell OK
UnitTestGrAFunDummyCreateFree OK
UnitTestGrAFunDummyGetType OK
UnitTestGrAFunDummy OK
UnitTestGrAFunWolframOriginalCreateFree OK
UnitTestGrAFunWolframOriginalGetType OK
UnitTestGrAFunWolframOriginalGetRule OK
UnitTestGrAFunWolframOriginal OK
UnitTestGrAFunNeuraNetCreateFree OK
UnitTestGrAFunNeuraNetGetType OK
UnitTestGrAFunNeuraNetNN OK
```

```
UnitTestGrAFunNeuraNet OK
UnitTestGrAFun OK
UnitTestGradAutomatonDummyCreateFree OK
UnitTestGradAutomatonDummyGet OK
UnitTestGradAutomatonDummyStep OK
UnitTestGradAutomatonDummy OK
UnitTestGradAutomatonWolframOriginalCreateFree OK
UnitTestGradAutomatonWolframOriginalGet OK
```



```
UnitTestGradAutomatonWolframOriginalStepPrintln OK
UnitTestGradAutomatonWolframOriginal OK
UnitTestGradAutomatonNeuraNetCreateFree OK
UnitTestGradAutomatonNeuraNetGet OK
UnitTestGradAutomatonNeuraNetStep OK
UnitTestGradAutomatonNeuraNet OK
UnitTestGradAutomaton OK
UnitTestAll OK
```

unitTestGradAutomatonWolframOriginalSave.json

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