

GSet

P. Baillehache

March 5, 2018

Contents

1	Interface	2
2	Code	14
2.1	gset.c	14
2.2	gset-inline.c	22
3	Makefile	40
4	Unit tests	41
5	Unit tests output	57

Introduction

GSet library is a C library to manipulate sets of data.

Elements of the GSet are void pointers toward any kind of data. These data must be allocated and freed separately. The GSet only provides a mean to manipulate sets of pointers toward these data.

The GSet offers functions to add elements (at first position, last position, given position, or sorting based on a float value), to access elements (at first position, last position, given position), to get index of first/last element pointing to a given data, to remove elements (at first position, last position, given position, or first/last/all pointing toward a given data), to search for data in elements (first one or last one), to print the set on a stream, to split, merge and sort the set.

The library provides also a GSetVecFloat structure with same interface as a GSet but whose contents is restrained to VecFloat structures.

The library also provides two iterator structures to run through a GSet forward or backward, and apply a user defined function on each element.

It uses the PBErr library.

1 Interface

```
// ***** GSET.H *****
#ifndef GSET_H
#define GSET_H

// ===== Include =====
#include <stdlib.h>
#include <stdio.h>
#include <stdbool.h>
#include <string.h>
#include "pberr.h"

// ===== Data structures =====

// Structure of one element of the GSet
struct GSetElem;
typedef struct GSetElem {
    // Pointer toward the data
    void* _data;
    // Pointer toward the next element in the GSet
    struct GSetElem* _next;
    // Pointer toward the previous element in the GSet
    struct GSetElem* _prev;
    // Value to sort element in the GSet, 0.0 by default
    float _sortVal;
} GSetElem;

// Structure of the GSet
typedef struct GSet {
    // Pointer toward the element at the head of the GSet
    GSetElem* _head;
    // Pointer toward the last element of the GSet
    GSetElem* _tail;
    // Number of element in the GSet
    int _nbElem;
} GSet;

// Structures of the GSet iterators
typedef struct GSetIterForward {
    // GSet attached to the iterator
    GSet* _set;
    // Current element
    GSetElem* _curElem;
} GSetIterForward;
```

```

typedef struct GSetIterBackward {
    // GSet attached to the iterator
    GSet* _set;
    // Current element
    GSetElem* _curElem;
} GSetIterBackward;

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

// Function to create a new GSet,
// Return a pointer toward the new GSet
GSet* GSetCreate(void);

// Static constructors for GSet
#if BUILDMODE != 0
inline
#endif
GSet GSetCreateStatic(void);

// Function to clone a GSet,
// Return a pointer toward the new GSet
GSet* GSetClone(GSet* that);

// Function to free the memory used by the GSet
void _GSetFree(GSet** s);

// Function to empty the GSet
#if BUILDMODE != 0
inline
#endif
void _GSetFlush(GSet* that);

// Return the number of element in the set
#if BUILDMODE != 0
inline
#endif
int _GSetNbElem(GSet* that);

// Function to print a GSet
// Use the function 'printData' to print the data pointed to by
// the elements, and print 'sep' between each element
// If printData is null, print the pointer value instead
void _GSetPrint(GSet* that, FILE* stream,
    void(*printData)(void* data, FILE* stream), char* sep);

// Function to insert an element pointing toward 'data' at the
// head of the GSet
#if BUILDMODE != 0
inline
#endif
void _GSetPush(GSet* that, void* data);

// Function to insert an element pointing toward 'data' at the
// position defined by 'v' sorting the set in increasing order
void _GSetAddSort(GSet* that, void* data, double v);

// Function to insert an element pointing toward 'data' at the
// 'iElem'-th position
// If 'iElem' is greater than or equal to the number of element
// in the GSet, elements pointing toward null data are added
// If the data is inserted inside the set, the current elements from
// the iElem-th elem are pushed

```

```

void _GSetInsert(GSet* that, void* data, int iElem);

// Function to insert an element pointing toward 'data' at the
// tail of the GSet
#if BUILDMODE != 0
inline
#endif
void _GSetAppend(GSet* that, void* data);

// Function to remove the element at the head of the GSet
// Return the data pointed to by the removed element, or null if the
// GSet is empty
#if BUILDMODE != 0
inline
#endif
void* _GSetPop(GSet* that);

// Function to remove the element at the tail of the GSet
// Return the data pointed to by the removed element, or null if the
// GSet is empty
#if BUILDMODE != 0
inline
#endif
void* _GSetDrop(GSet* that);

// Function to remove the element at the 'iElem'-th position of the GSet
// Return the data pointed to by the removed element
#if BUILDMODE != 0
inline
#endif
void* _GSetRemove(GSet* that, int iElem);

// Function to remove the element 'elem' of the GSet
// Return the data pointed to by the removed element
// The GSetElem is freed and *elem == NULL after calling this function
#if BUILDMODE != 0
inline
#endif
void* _GSetRemoveElem(GSet* that, GSetElem** elem);

// Function to remove the first element of the GSet pointing to 'data'
// If there is no element pointing to 'data' do nothing
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveFirst(GSet* that, void* data);

// Function to remove the last element of the GSet pointing to 'data'
// If there is no element pointing to 'data' do nothing
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveLast(GSet* that, void* data);

// Function to remove all the selement of the GSet pointing to 'data'
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveAll(GSet* that, void* data);

// Function to get the data at the 'iElem'-th position of the GSet

```

```

// without removing it
#if BUILDMODE != 0
inline
#endif
void* _GSetGet(GSet* that, int iElem);

// Function to get the element at the 'iElem'-th position of the GSet
// without removing it
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetElem(GSet* that, int iElem);

// Function to get the index of the first element of the GSet
// which point to 'data'
// Return -1 if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
int _GSetGetIndexFirst(GSet* that, void* data);

// Function to get the index of the last element of the GSet
// which point to 'data'
// Return -1 if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
int _GSetGetIndexLast(GSet* that, void* data);

// Function to get the first element of the GSet
// which point to 'data'
// Return NULL if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetFirstElem(GSet* that, void* data);

// Function to get the last element of the GSet
// which point to 'data'
// Return NULL if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetLastElem(GSet* that, void* data);

// Function to sort the element of the gset in increasing order of
// _sortVal
void _GSetSort(GSet* that);

// Merge the GSet 'set' at the end of the GSet 'that'
// 'that' and 'set' can be empty
// After calling this function 'set' is empty
#if BUILDMODE != 0
inline
#endif
void _GSetMerge(GSet* that, GSet* set);

// Split the GSet at the GSetElem 'e'
// 'e' must be an element of the set
// the set new end is the element before 'e', the set becomes empty if
// 'e' was the first element
// Return a new GSet starting with 'e', or NULL if 'e' is not

```

```

// an element of the set
#if BUILDMODE != 0
inline
#endif
GSet* _GSetSplit(GSet* that, GSetElem* e);

// Append the element of the GSet 'set' at the end of the GSet 'that'
// 'that' and 'set' can be empty
#if BUILDMODE != 0
inline
#endif
void _GSetAppendSet(GSet* that, GSet* set);

// Append the element of the GSet 'that' at the end of the GSet 'set'
// Elements are kept sorted
// 'that' and 'set' can be empty
#if BUILDMODE != 0
inline
#endif
void _GSetAppendSortedSet(GSet* that, GSet* set);

// Switch the 'iElem'-th and 'jElem'-th element of the set
#if BUILDMODE != 0
inline
#endif
void _GSetSwitch(GSet* that, int iElem, int jElem);

// Set the sort value of the GSetElem 'that' to 'v'
#if BUILDMODE != 0
inline
#endif
void GSetElemSetSortVal(GSetElem* that, float v);

// Move the 'iElem'-th element to the 'pos' index in the GSet
void _GSetMoveElem(GSet* that, int iElem, int pos);

// Create a new GSetIterForward for the GSet 'set'
// The iterator is reset upon creation
GSetIterForward* _GSetIterForwardCreate(GSet* set);
#if BUILDMODE != 0
inline
#endif
GSetIterForward _GSetIterForwardCreateStatic(GSet* set);

// Create a new GSetIterBackward for the GSet 'set'
// The iterator is reset upon creation
GSetIterBackward* _GSetIterBackwardCreate(GSet* set);
#if BUILDMODE != 0
inline
#endif
GSetIterBackward _GSetIterBackwardCreateStatic(GSet* set);

// Free the memory used by a GSetIterForward (not by its attached GSet)
// Do nothing if arguments are invalid
void GSetIterForwardFree(GSetIterForward** that);

// Free the memory used by a GSetIterBackward (not by its attached GSet)
// Do nothing if arguments are invalid
void GSetIterBackwardFree(GSetIterBackward** that);

// Clone a GSetIterForward
GSetIterForward* GSetIterForwardClone(GSetIterForward* that);

```

```

// Clone a GSetIterBackward
GSetIterBackward* GSetIterBackwardClone(GSetIterBackward* that);

// Reset the GSetIterForward to its starting position
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardReset(GSetIterForward* that);

// Reset the GSetIterBackward to its starting position
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardReset(GSetIterBackward* that);

// Step the GSetIterForward
// Return false if we couldn't step
// Return true else
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardStep(GSetIterForward* that);

// Step the GSetIterBackward
// Return false if we couldn't step
// Return true else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardStep(GSetIterBackward* that);

// Apply a function to all elements of the GSet of the GSetIterForward
// The iterator is first reset, then the function is apply sequentially
// using the Step function of the iterator
// The applied function takes to void* arguments: 'data' is the _data
// property of the nodes, 'param' is a hook to allow the user to pass
// parameters to the function through a user-defined structure
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardApply(GSetIterForward* that,
    void(*fun)(void* data, void* param), void* param);

// Apply a function to all elements of the GSet of the GSetIterBackward
// The iterator is first reset, then the function is apply sequentially
// using the Step function of the iterator
// The applied function takes to void* arguments: 'data' is the _data
// property of the nodes, 'param' is a hook to allow the user to pass
// parameters to the function through a user-defined structure
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardApply(GSetIterBackward* that,
    void(*fun)(void* data, void* param), void* param);

// Return true if the iterator is at the start of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif

```

```

bool GSetIterForwardIsFirst(GSetIterForward* that);

// Return true if the iterator is at the start of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardIsFirst(GSetIterBackward* that);

// Return true if the iterator is at the end of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardIsLast(GSetIterForward* that);

// Return true if the iterator is at the end of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardIsLast(GSetIterBackward* that);

// Change the attached set of the iterator, and reset it
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardSetGSet(GSetIterForward* that, GSet* set);

// Change the attached set of the iterator, and reset it
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardSetGSet(GSetIterBackward* that, GSet* set);

// Return the data currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
void* GSetIterForwardGet(GSetIterForward* that);

// Return the data currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
void* GSetIterBackwardGet(GSetIterBackward* that);

// Return the element currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
GSetElem* GSetIterForwardGetElem(GSetIterForward* that);

// Return the element currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
GSetElem* GSetIterBackwardGetElem(GSetIterBackward* that);

```



```

// Remove the element currently pointed to by the iterator
// The iterator is moved forward to the next element
// Return false if we couldn't move
// Return true else
// It's the responsibility of the user to delete the content of the
// element prior to calling this function
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardRemoveElem(GSetIterForward* that);

// Remove the element currently pointed to by the iterator
// The iterator is moved backward to the next element
// Return false if we couldn't move
// Return true else
// It's the responsibility of the user to delete the content of the
// element prior to calling this function
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardRemoveElem(GSetIterBackward* that);

// ===== Typed GSet =====

#ifndef VecFloat
typedef struct VecFloat VecFloat;
#endif
#ifndef VecFloat2D
typedef struct VecFloat2D VecFloat2D;
#endif
#ifndef VecFloat3D
typedef struct VecFloat3D VecFloat3D;
#endif
typedef struct GSetVecFloat {GSet _set;} GSetVecFloat;
#define GSetVecFloatCreate() ((GSetVecFloat*)GSetCreate())
inline GSetVecFloat GSetVecFloatCreateStatic(void)
{GSetVecFloat ret = {._set=GSetCreateStatic()}; return ret;}
inline GSetVecFloat* GSetVecFloatClone(GSetVecFloat* that)
{return (GSetVecFloat*)GSetClone((GSet*)that);}
inline VecFloat* _GSetVecFloatGet(GSetVecFloat* that, int iElem)
{return (VecFloat*)_GSetGet((GSet*)that, iElem);}
inline VecFloat* _GSetVecFloatPop(GSetVecFloat* that)
{return (VecFloat*)_GSetPop((GSet*)that);}
inline VecFloat* _GSetVecFloatDrop(GSetVecFloat* that)
{return (VecFloat*)_GSetDrop((GSet*)that);}
inline VecFloat* _GSetVecFloatRemove(GSetVecFloat* that, int iElem)
{return (VecFloat*)_GSetRemove((GSet*)that, iElem);}
inline VecFloat* _GSetVecFloatRemoveElem(GSetVecFloat* that,
GSetElem** elem)
{return (VecFloat*)_GSetRemoveElem((GSet*)that, elem);}

// ===== Generic functions =====

#define GSetFree(Set) _Generic(Set, \
    GSet*: _GSetFree, \
    GSetVecFloat*: _GSetFree, \
    default: PBErrInvalidPolymorphism)((GSet**)(Set))

#define GSetPush(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetPush), \
    GSetVecFloat*: _Generic(Data, \

```

```

    VecFloat*: _GSetPush, \
    VecFloat2D*: _GSetPush, \
    VecFloat3D*: _GSetPush, \
    default: PBErrInvalidPolymorphism), \
default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetAddSort(Set, Data, Value) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetAddSort), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetAddSort, \
        VecFloat2D*: _GSetAddSort, \
        VecFloat3D*: _GSetAddSort, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data), Value)

#define GSetInsert(Set, Data, Pos) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetInsert), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetInsert, \
        VecFloat2D*: _GSetInsert, \
        VecFloat3D*: _GSetInsert, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data), Pos)

#define GSetAppend(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetAppend), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetAppend, \
        VecFloat2D*: _GSetAppend, \
        VecFloat3D*: _GSetAppend, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetRemoveFirst(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetRemoveFirst), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetRemoveFirst, \
        VecFloat2D*: _GSetRemoveFirst, \
        VecFloat3D*: _GSetRemoveFirst, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetRemoveLast(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetRemoveLast), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetRemoveLast, \
        VecFloat2D*: _GSetRemoveLast, \
        VecFloat3D*: _GSetRemoveLast, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetRemoveAll(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetRemoveAll), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetRemoveAll, \
        VecFloat2D*: _GSetRemoveAll, \

```

```

    VecFloat3D*: _GSetRemoveAll, \
    default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetGetIndexFirst(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetGetIndexFirst), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetGetIndexFirst, \
        VecFloat2D*: _GSetGetIndexFirst, \
        VecFloat3D*: _GSetGetIndexFirst, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetGetIndexLast(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetGetIndexLast), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetGetIndexLast, \
        VecFloat2D*: _GSetGetIndexLast, \
        VecFloat3D*: _GSetGetIndexLast, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetGetFirstElem(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetGetFirstElem), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetGetFirstElem, \
        VecFloat2D*: _GSetGetFirstElem, \
        VecFloat3D*: _GSetGetFirstElem, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetGetLastElem(Set, Data) _Generic(Set, \
    GSet*: _Generic(Data, \
        default: _GSetGetLastElem), \
    GSetVecFloat*: _Generic(Data, \
        VecFloat*: _GSetGetLastElem, \
        VecFloat2D*: _GSetGetLastElem, \
        VecFloat3D*: _GSetGetLastElem, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), (void*)(Data))

#define GSetPrint(Set, Stream, Fun, Sep) _Generic(Set, \
    GSet*: _GSetPrint, \
    GSetVecFloat*: _GSetPrint, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), Stream, Fun, Sep)

#define GSetFlush(Set) _Generic(Set, \
    GSet*: _GSetFlush, \
    GSetVecFloat*: _GSetFlush, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetNbElem(Set) _Generic(Set, \
    GSet*: _GSetNbElem, \
    GSetVecFloat*: _GSetNbElem, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetPop(Set) _Generic(Set, \
    GSet*: _GSetPop, \
    GSetVecFloat*: _GSetVecFloatPop, \

```

```

    default: PBErriInvalidPolymorphism)((GSet*)(Set))

#define GSetDrop(Set) _Generic(Set, \
    GSet*: _GSetDrop, \
    GSetVecFloat*: _GSetVecFloatDrop, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set))

#define GSetRemove(Set, Pos) _Generic(Set, \
    GSet*: _GSetRemove, \
    GSetVecFloat*: _GSetVecFloatRemove, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set), Pos)

#define GSetRemoveElem(Set, Elem) _Generic(Set, \
    GSet*: _GSetRemoveElem, \
    GSetVecFloat*: _GSetVecFloatRemoveElem, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set), Elem)

#define GSetGet(Set, Pos) _Generic(Set, \
    GSet*: _GSetGet, \
    GSetVecFloat*: _GSetVecFloatGet, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set), Pos)

#define GSetGetElem(Set, Pos) _Generic(Set, \
    GSet*: _GSetGetElem, \
    GSetVecFloat*: _GSetGetElem, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set), Pos)

#define GSetSort(Set) _Generic(Set, \
    GSet*: _GSetSort, \
    GSetVecFloat*: _GSetSort, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set))

#define GSetMerge(IntoSet, MergedSet) _Generic(IntoSet, \
    GSet*: _Generic(MergedSet, \
        GSet*: _GSetMerge, \
        GSetVecFloat*: _GSetMerge, \
        default: PBErriInvalidPolymorphism), \
    GSetVecFloat*: _Generic(MergedSet, \
        GSet*: _GSetMerge, \
        GSetVecFloat*: _GSetMerge, \
        default: PBErriInvalidPolymorphism), \
    default: PBErriInvalidPolymorphism)((GSet*)(IntoSet), \
        (GSet*)(MergedSet))

#define GSetSplit(Set, Elem) _Generic(Set, \
    GSet*: _GSetSplit, \
    GSetVecFloat*: _GSetSplit, \
    default: PBErriInvalidPolymorphism)((GSet*)(Set), Elem)

#define GSetAppendSet(IntoSet, AppendSet) _Generic(IntoSet, \
    GSet*: _Generic(AppendSet, \
        GSet*: _GSetAppendSet, \
        GSetVecFloat*: _GSetAppendSet, \
        default: PBErriInvalidPolymorphism), \
    GSetVecFloat*: _Generic(AppendSet, \
        GSet*: _GSetAppendSet, \
        GSetVecFloat*: _GSetAppendSet, \
        default: PBErriInvalidPolymorphism), \
    default: PBErriInvalidPolymorphism)((GSet*)(IntoSet), \
        (GSet*)(AppendSet))

#define GSetAppendSortedSet(IntoSet, AppendSet) _Generic(IntoSet, \

```

```

GSet*: _Generic(AppendSet, \
    GSet*: _GSetAppendSortedSet, \
    GSetVecFloat*: _GSetAppendSortedSet, \
    default: PBErrInvalidPolymorphism), \
GSetVecFloat*: _Generic(AppendSet, \
    GSet*: _GSetAppendSortedSet, \
    GSetVecFloat*: _GSetAppendSortedSet, \
    default: PBErrInvalidPolymorphism), \
default: PBErrInvalidPolymorphism)((GSet*)(IntoSet), \
    (GSet*)(AppendSet))

#define GSetSwitch(Set, PosA, PosB) _Generic(Set, \
    GSet*: _GSetSwitch, \
    GSetVecFloat*: _GSetSwitch, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), PosA, PosB)

#define GSetMoveElem(Set, From, To) _Generic(Set, \
    GSet*: _GSetMoveElem, \
    GSetVecFloat*: _GSetMoveElem, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set), From, To)

#define GSetIterForwardCreate(Set) _Generic(Set, \
    GSet*: _GSetIterForwardCreate, \
    GSetVecFloat*: _GSetIterForwardCreate, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetIterForwardCreateStatic(Set) _Generic(Set, \
    GSet*: _GSetIterForwardCreateStatic, \
    GSetVecFloat*: _GSetIterForwardCreateStatic, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetIterBackwardCreate(Set) _Generic(Set, \
    GSet*: _GSetIterBackwardCreate, \
    GSetVecFloat*: _GSetIterBackwardCreate, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetIterBackwardCreateStatic(Set) _Generic(Set, \
    GSet*: _GSetIterBackwardCreateStatic, \
    GSetVecFloat*: _GSetIterBackwardCreateStatic, \
    default: PBErrInvalidPolymorphism)((GSet*)(Set))

#define GSetIterFree(IterRef) _Generic(IterRef, \
    GSetIterForward*: GSetIterForwardFree, \
    GSetIterBackward*: GSetIterBackwardFree, \
    default: PBErrInvalidPolymorphism)(IterRef)

#define GSetIterClone(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardClone, \
    GSetIterBackward*: GSetIterBackwardClone, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterReset(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardReset, \
    GSetIterBackward*: GSetIterBackwardReset, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterStep(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardStep, \
    GSetIterBackward*: GSetIterBackwardStep, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterApply(Iter, Fun, Param) _Generic(Iter, \

```

```

GSetIterForward*: GSetIterForwardApply, \
GSetIterBackward*: GSetIterBackwardApply, \
default: PBErrInvalidPolymorphism)(Iter, Fun, Param)

#define GSetIterIsFirst(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardIsFirst, \
    GSetIterBackward*: GSetIterBackwardIsFirst, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterIsLast(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardIsLast, \
    GSetIterBackward*: GSetIterBackwardIsLast, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterSetGSet(Iter, Set) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardSetGSet, \
    GSetIterBackward*: GSetIterBackwardSetGSet, \
    default: PBErrInvalidPolymorphism)(Iter, Set)

#define GSetIterGet(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardGet, \
    GSetIterBackward*: GSetIterBackwardGet, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterGetElem(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardGetElem, \
    GSetIterBackward*: GSetIterBackwardGetElem, \
    default: PBErrInvalidPolymorphism)(Iter)

#define GSetIterRemoveElem(Iter) _Generic(Iter, \
    GSetIterForward*: GSetIterForwardRemoveElem, \
    GSetIterBackward*: GSetIterBackwardRemoveElem, \
    default: PBErrInvalidPolymorphism)(Iter)

// ===== Inlineer =====

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

#endif

```

2 Code

2.1 gset.c

```

// ***** GSET.C *****

// ===== Include =====
#include "gset.h"
#if BUILDMODE == 0
#include "gset-inline.c"
#endif

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

// Function to create a new GSet,
// Return a pointer toward the new GSet

```

```

GSet* GSetCreate(void) {
    // Allocate memory for the GSet
    GSet* s = PBErrMalloc(GSetErr, sizeof(GSet));
    // Set the pointer to head and tail, and the number of element
    s->_head = NULL;
    s->_tail = NULL;
    s->_nbElem = 0;
    // Return the new GSet
    return s;
}

// Function to clone a GSet,
// Return a pointer toward the new GSet
GSet* GSetClone(GSet* that) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
    // Create the clone
    GSet* c = GSetCreate();
    // Set a pointer to the head of the set
    GSetElem* ptr = that->_head;
    // While the pointer is not at the end of the set
    while (ptr != NULL) {
        // Append the data of the current pointer to the clone
        GSetAppend(c, ptr->_data);
        // Copy the sort value
        c->_tail->_sortVal = ptr->_sortVal;
        // Move the pointer to the next element
        ptr = ptr->_next;
    }
    // Return the clone
    return c;
}

// Function to free the memory used by the GSet
void _GSetFree(GSet** that) {
    if (that == NULL || *that == NULL) return;
    // Empty the GSet
    GSetFlush(*that);
    // Free the memory
    free(*that);
    // Set the pointer to null
    *that = NULL;
}

// Function to print a GSet
// Use the function 'printData' to print the data pointed to by
// the elements, and print 'sep' between each element
// If printData is null, print the pointer value instead
// Do nothing if arguments are invalid
void _GSetPrint(GSet* that, FILE* stream,
    void(*printData)(void* data, FILE* stream), char* sep) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
}

```

```

    if (stream == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'stream' is null");
        PBErrCatch(GSetErr);
    }
    if (sep == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'sep' is null");
        PBErrCatch(GSetErr);
    }
}
#endif
// Set a pointer to the head element
GSetElem* p = that->_head;
// While the pointer hasn't reach the end
while (p != NULL) {
    // If there is a print function for the data
    if (printData != NULL) {
        // Use the argument function to print the data of the
        // current element
        (*printData)(p->_data, stream);
    } else {
        // Print the pointer value instead
        fprintf(stream, "%p", p->_data);
    }
    // Move to the next element
    p = p->_next;
    // If there is a next element
    if (p != NULL)
        // Print the separator
        fprintf(stream, "%s", sep);
}
// Flush the stream
fflush(stream);
}

// Function to insert an element pointing toward 'data' at the
// position defined by 'v' sorting the set in increasing order
void _GSetAddSort(GSet* that, void* data, double v) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
// Allocate memory for the new element
GSetElem* e = PBErrMalloc(GSetErr, sizeof(GSetElem));
// Memorize the pointer toward data
e->_data = data;
// Memorize the sorting value
e->_sortVal = v;
// If the GSet is empty
if (that->_nbElem == 0) {
    // Add the element at the head of the GSet
    that->_head = e;
    that->_tail = e;
    e->_next = NULL;
    e->_prev = NULL;
} else {
    // Set a pointer to the head of the GSet
    GSetElem* p = that->_head;

```



```

// While the pointed element has a lower value than the
// new element, move the pointer to the next element
while (p != NULL && p->_sortVal <= v)
    p = p->_next;
// Set the next element of the new element to the current element
e->_next = p;
// If the current element is not null
if (p != NULL) {
    // Insert the new element inside the list of elements before p
    e->_prev = p->_prev;
    if (p->_prev != NULL)
        p->_prev->_next = e;
    else
        that->_head = e;
    p->_prev = e;
} else {
    // Else, if the current element is null
    // Insert the new element at the tail of the GSet
    e->_prev = that->_tail;
    if (that->_tail != NULL)
        that->_tail->_next = e;
    that->_tail = e;
    if (that->_head == NULL)
        that->_head = e;
}
}
// Increment the number of elements
++(that->_nbElem);
}

// Function to insert an element pointing toward 'data' at the
// 'iElem'-th position
// If 'iElem' is greater than or equal to the number of element
// in the GSet, elements pointing toward null data are added
// If the data is inserted inside the set, the current elements from
// the iElem-th elem are pushed
void GSetInsert(GSet* that, void* data, int iElem) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (iElem < 0) {
        GSetErr->_type = PBErrTypeInvalidArg;
        sprintf(GSetErr->_msg, "'iElem' is invalid (%d>=0)", iElem);
        PBErrCatch(GSetErr);
    }
#endif
    // If iElem is greater than the number of elements, append
    // elements pointing toward null data to fill in the gap
    while (iElem > that->_nbElem)
        GSetAppend(that, NULL);
    // If iElem is in the list of element or at the tail
    if (iElem <= that->_nbElem + 1) {
        // If the insert position is the head
        if (iElem == 0) {
            // Push the data
            GSetPush(that, data);
        } else if (iElem == that->_nbElem) {
            // Append data

```

```

        GSetAppend(that, data);
// Else, the insert position is inside the list
} else {
    // Allocate memory for the new element
    GSetElem* e = PBErrMalloc(GSetErr, sizeof(GSetElem));
    // Memorize the pointer toward data
    e->_data = data;
    // By default set the sorting value to 0.0
    e->_sortVal = 0.0;
    // Set a pointer toward the head of the GSet
    GSetElem* p = that->_head;
    // Move the pointer to the iElem-th element
    for (int i = iElem; i > 0 && p != NULL; --i, p = p->_next);
    // Insert the element before the pointer
    e->_next = p;
    e->_prev = p->_prev;
    p->_prev = e;
    e->_prev->_next = e;
    // Increment the number of elements
    ++(that->_nbElem);
}
}
}

// Function to sort the element of the gset in increasing order of
// _sortVal
// Do nothing if arguments are invalid or the sort failed
static GSet* GSetSortRec(GSet** s);
void _GSetSort(GSet* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Create a clone of the original set
    GSet* clone = GSetClone(that);
    // Create recursively the sorted set
    GSet* res = GSetSortRec(&clone);
    // If we could sort the set
    if (res != NULL) {
        // Update the original set with the result one
        GSetFlush(that);
        memcpy(that, res, sizeof(GSet));
        // Free the memory used by the result set
        free(res);
        res = NULL;
    }
}

GSet* GSetSortRec(GSet** s) {
    // Declare a variable for the result
    GSet* res = NULL;
    // If the set contains no element or one element
    if ((*s)->_nbElem == 0 || (*s)->_nbElem == 1) {
        // Return the set
        res = *s;
    }
    // Else, the set contains several elements
    else {
        // Create two sets, one for elements lower than the pivot
        // one for elements greater or equal than the pivot
        GSet* lower = GSetCreate();

```

```

GSet* greater = GSetCreate();
res = GSetCreate();
// Declare a variable to memorize the pivot, which is equal
// to the sort value of the first element of the set
float pivot = (*s)->_head->_sortVal;
// Pop the pivot and put it in the result
void* data = GSetPop(*s);
GSetAppend(res, data);
res->_head->_sortVal = pivot;
// Pop all the elements one by one from the set
while ((*s)->_nbElem != 0) {
    // Declare a variable to memorize the sort value of the head
    // element
    float val = (*s)->_head->_sortVal;
    // Pop the head element
    data = GSetPop(*s);
    // If the popped element has a sort value lower than the pivot
    if (val < pivot) {
        // Insert it in the lower set
        GSetAppend(lower, data);
        // Copy the sort value
        lower->_tail->_sortVal = val;
    } // Else, the popped element has a sort value greater than or
    // equal to the pivot
    } else {
        // Insert it in the greater set
        GSetAppend(greater, data);
        // Copy the sort value
        greater->_tail->_sortVal = val;
    }
}
// At the end of the loop the original set is empty and we
// don't need it anymore
GSetFree(s);
// Sort the two half
GSet* sortedLower = GSetSortRec(&lower);
GSet* sortedGreater = GSetSortRec(&greater);
// Merge back the sorted two halves and the pivot
GSetMerge(sortedLower, res);
GSetMerge(sortedLower, sortedGreater);
GSetFree(&res);
res = sortedLower;
GSetFree(&sortedGreater);
}
// Return the result
return res;
}

// Move the 'iElem'-th element to the 'pos' index in the GSet
void _GSetMoveElem(GSet* that, int iElem, int pos) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GenBrushErr->_type = PBErrTypeNullPointer;
        sprintf(GenBrushErr->_msg, "'that' is null");
        PBErrCatch(GenBrushErr);
    }
    if (iElem < 0 || iElem >= GSetNbElem(that)) {
        GenBrushErr->_type = PBErrTypeInvalidArg;
        sprintf(GenBrushErr->_msg, "'iElem' is invalid (0<=%d<%d)",
            iElem, GSetNbElem(that));
        PBErrCatch(GenBrushErr);
    }
}

```

```

    if (pos < 0 || pos >= GSetNbElem(that)) {
        GenBrushErr->_type = PBErrTypeInvalidArg;
        sprintf(GenBrushErr->_msg, "'pos' is invalid (0<=%d<%d)",
            pos, GSetNbElem(that));
        PBErrCatch(GenBrushErr);
    }
#endif
    // If the origin and destination position are the same
    // there is nothing to do
    if (iElem == pos)
        return;
    // Get a pointer to the mmoved element
    GSetElem* elem = GSetGetElem(that, iElem);
    //Declare two variables to memorize the sort value and data
    // of the moved element
    float sortVal = elem->_sortVal;
    void* data = elem->_data;
    // Remove the moved element
    GSetRemove(that, iElem);
    // Insert new element
    GSetInsert(that, data, pos);
    // Get a pointer to the newly inserted element
    elem = GSetGetElem(that, pos);
    // Correct the sorted value with the original value
    elem->_sortVal = sortVal;
}

// Create a new GSetIterForward for the GSet 'set'
// The iterator is reset upon creation
GSetIterForward* _GSetIterForwardCreate(GSet* set) {
#ifdef BUILDMODE == 0
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Allocate memory
    GSetIterForward* ret =
        PBErrMalloc(GSetErr, sizeof(GSetIterForward));
    // Set properties
    ret->_set = set;
    ret->_curElem = set->_head;
    // Return the new iterator
    return ret;
}

// Create a new GSetIterBackward for the GSet 'set'
// The iterator is reset upon creation
GSetIterBackward* _GSetIterBackwardCreate(GSet* set) {
#ifdef BUILDMODE == 0
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Allocate memory
    GSetIterBackward* ret =
        PBErrMalloc(GSetErr, sizeof(GSetIterBackward));
    // Set properties
    ret->_set = set;

```

```

    ret->_curElem = set->_tail;
    // Return the new iterator
    return ret;
}

// Free the memory used by a GSetIterForward (not by its attached GSet)
// Do nothing if arguments are invalid
void GSetIterForwardFree(GSetIterForward** that) {
    // Check arguments
    if (that == NULL || *that == NULL)
        return;
    (*that)->_set = NULL;
    (*that)->_curElem = NULL;
    free(*that);
    *that = NULL;
}

// Free the memory used by a GSetIterBackward (not by its attached GSet)
// Do nothing if arguments are invalid
void GSetIterBackwardFree(GSetIterBackward** that) {
    // Check arguments
    if (that == NULL || *that == NULL)
        return;
    (*that)->_set = NULL;
    (*that)->_curElem = NULL;
    free(*that);
    *that = NULL;
}

// Clone a GSetIterForward
GSetIterForward* GSetIterForwardClone(GSetIterForward* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Create the clone
    GSetIterForward* ret = GSetIterForwardCreate(that->_set);
    ret->_curElem = that->_curElem;
    // return the clone
    return ret;
}

// Clone a GSetIterBackward
GSetIterBackward* GSetIterBackwardClone(GSetIterBackward* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Create the clone
    GSetIterBackward* ret = GSetIterBackwardCreate(that->_set);
    ret->_curElem = that->_curElem;
    // return the clone
    return ret;
}

```

2.2 gset-inline.c

```
// ***** GSET-INLINE.C *****

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

// Static constructors for GSet
#if BUILDMODE != 0
inline
#endif
GSet GSetCreateStatic(void) {
    // Declare a GSet and set the properties
    GSet s = {._head = NULL, ._tail = NULL, ._nbElem = 0};
    // Return the GSet
    return s;
}

// Function to empty the GSet
#if BUILDMODE != 0
inline
#endif
void _GSetFlush(GSet* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
#endif
    // Pop element until the GSet is null
    while (GSetPop(that) || that->_nbElem > 0);
}

// Function to insert an element pointing toward 'data' at the
// head of the GSet
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void _GSetPush(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
#endif
    // Allocate memory for the new element
    GSetElem* e = PErrMalloc(GSetErr, sizeof(GSetElem));
    // Memorize the pointer toward data
    e->_data = data;
    // By default set the sorting value to 0.0
    e->_sortVal = 0.0;
    // Add the element at the head of the GSet
    e->_prev = NULL;
    if (that->_head != NULL)
        that->_head->_prev = e;
    e->_next = that->_head;
    that->_head = e;
    if (that->_tail == NULL)
        that->_tail = e;
    // Increment the number of elements in the GSet
}
```

```

    ++(that->_nbElem);
}

// Function to insert an element pointing toward 'data' at the
// tail of the GSet
#if BUILDMODE != 0
inline
#endif
void _GSetAppend(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    GSetElem* e = PBErrMalloc(GSetErr, sizeof(GSetElem));
    if (e != NULL) {
        e->_data = data;
        e->_sortVal = 0.0;
        e->_prev = that->_tail;
        e->_next = NULL;
        if (that->_tail != NULL)
            that->_tail->_next = e;
        that->_tail = e;
        if (that->_head == NULL)
            that->_head = e;
        ++(that->_nbElem);
    }
}

// Function to remove the element at the head of the GSet
// Return the data pointed to by the removed element, or null if the
// GSet is empty
#if BUILDMODE != 0
inline
#endif
void* _GSetPop(GSet* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    void* ret = NULL;
    GSetElem* p = that->_head;
    if (p != NULL) {
        ret = p->_data;
        that->_head = p->_next;
        if (p->_next != NULL)
            p->_next->_prev = NULL;
        p->_next = NULL;
        p->_data = NULL;
        if (that->_tail == p)
            that->_tail = NULL;
        free(p);
        --(that->_nbElem);
    }
    return ret;
}

```

```

// Function to remove the element at the tail of the GSet
// Return the data pointed to by the removed element, or null if the
// GSet is empty
#if BUILDMODE != 0
inline
#endif
void* _GSetDrop(GSet* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
#endif
    void* ret = NULL;
    GSetElem* p = that->_tail;
    if (p != NULL) {
        ret = p->_data;
        that->_tail = p->_prev;
        if (p->_prev != NULL)
            p->_prev->_next = NULL;
        p->_prev = NULL;
        p->_data = NULL;
        if (that->_head == p)
            that->_head = NULL;
        free(p);
        --(that->_nbElem);
    }
    return ret;
}

// Function to remove the element 'elem' of the GSet
// Return the data pointed to by the removed element
// The GSetElem is freed and *elem == NULL after calling this function
#if BUILDMODE != 0
inline
#endif
void* _GSetRemoveElem(GSet* that, GSetElem** elem) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
    if (elem == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'elem' is null");
        PErrCatch(GSetErr);
    }
    if (*elem == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'*elem' is null");
        PErrCatch(GSetErr);
    }
#endif
    // Variable to memorize the return value
    void* ret = NULL;
    // Memorize the data at iElem-th position
    ret = (*elem)->_data;
    // Remove the element
    if ((*elem)->_next != NULL)
        (*elem)->_next->_prev = (*elem)->_prev;

```



```

    if ((*elem)->_prev != NULL)
        (*elem)->_prev->_next = (*elem)->_next;
    if (that->_head == (*elem))
        that->_head = (*elem)->_next;
    if (that->_tail == (*elem))
        that->_tail = (*elem)->_prev;
    (*elem)->_next = NULL;
    (*elem)->_prev = NULL;
    (*elem)->_data = NULL;
    free((*elem));
    *elem = NULL;
    // Decrement the number of elements
    --(that->_nbElem);
    // Return the data
    return ret;
}

// Function to remove the first element of the GSet pointing to 'data'
// If there is no element pointing to 'data' do nothing
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveFirst(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Get the first element pointing to 'data'
    GSetElem* elem = GSetGetFirstElem(that, data);
    // If we could find an element
    if (elem != NULL)
        // Remove this element
        while (GSetRemoveElem(that, &elem) && false);
}

// Function to remove the last element of the GSet pointing to 'data'
// If there is no element pointing to 'data' do nothing
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveLast(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Get the last element pointing to 'data'
    GSetElem* elem = GSetGetLastElem(that, data);
    // If we could find an element
    if (elem != NULL)
        // Remove this element
        while (GSetRemoveElem(that, &elem) && false);
}

// Function to remove the element at the 'iElem'-th position of the GSet
// Return the data pointed to by the removed element
#if BUILDMODE != 0

```

```

inline
#endif
void* _GSetRemove(GSet* that, int iElem) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
    if (iElem < 0 || iElem >= that->_nbElem) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'iElem' is invalid (0<=%d<%d)",
            iElem, that->_nbElem);
        PErrCatch(GSetErr);
    }
#endif
    // Variable to memorize the return value
    void* ret = NULL;
    // Set a pointer to the head of the Gset
    GSetElem* p = that->_head;
    // Move the pointer to the iElem-th element
    for (int i = iElem; i > 0 && p != NULL; --i, p = p->_next);
    // Memorize the data at iElem-th position
    ret = p->_data;
    // Remove the element
    if (p->_next != NULL)
        p->_next->_prev = p->_prev;
    if (p->_prev != NULL)
        p->_prev->_next = p->_next;
    if (that->_head == p)
        that->_head = p->_next;
    if (that->_tail == p)
        that->_tail = p->_prev;
    p->_next = NULL;
    p->_prev = NULL;
    p->_data = NULL;
    free(p);
    // Decrement the number of elements
    --(that->_nbElem);
    // Return the data
    return ret;
}

// Function to remove all the selement of the GSet pointing to 'data'
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void _GSetRemoveAll(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
#endif
    // Set a pointer toward the tail of the GSet
    GSetElem* p = that->_tail;
    // Loop on elements until we reached the head of the list
    while (p != NULL) {
        // If the element points toward data
        if (p->_data == data) {

```

```

        // Memorize the previous element before deleting
        GSetElem* prev = p->_prev;
        // Remove the element
        GSetRemoveElem(that, &p);
        // Continue with previous element
        p = prev;
    // Else, the element doesn't point toward data
    } else {
        // Continue with previous element
        p = p->_prev;
    }
}
}

// Function to get the data at the 'iElem'-th position of the GSet
// without removing it
#if BUILDMODE != 0
inline
#endif
void* _GSetGet(GSet* that, int iElem) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
        if (iElem < 0 || iElem >= that->_nbElem) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'iElem' is invalid (0<=%d<=%d)",
                    iElem, that->_nbElem);
            PBErrCatch(GSetErr);
        }
    #endif
    // Set a pointer for the return value
    void* ret = NULL;
    // Get the iElem-th element
    GSetElem* e = GSetGetElem(that, iElem);
    // Get the data of the element
    ret = e->_data;
    // Return the data
    return ret;
}

// Function to get the element at the 'iElem'-th position of the GSet
// without removing it
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetElem(GSet* that, int iElem) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
        if (iElem < 0 || iElem >= that->_nbElem) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'iElem' is invalid (0<=%d<=%d)",
                    iElem, that->_nbElem);
            PBErrCatch(GSetErr);
        }
    #endif
}

```

```

    // Set a pointer for the return value
    GSetElem* ret = NULL;
    // Set the pointer to the head of the GSet
    ret = that->_head;
    // Move to the next element iElem times
    for (int i = iElem; i > 0 && ret != NULL; --i, ret = ret->_next);
    // Return the element
    return ret;
}

// Function to get the index of the first element of the GSet
// which point to 'data'
// Return -1 if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
int _GSetGetIndexFirst(GSet* that, void* data) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
    // Set a pointer toward the head of the GSet
    GSetElem* p = that->_head;
    // Set a variable to memorize index
    int index = 0;
    // Loop on elements until we have found the
    // requested data or reached the end of the list
    while (p != NULL && p->_data != data) {
        ++index;
        p = p->_next;
    }
    // If the pointer is null it means the data wasn't in the GSet
    if (p == NULL)
        index = -1;
    // Return the index
    return index;
}

// Function to get the index of the last element of the GSet
// which point to 'data'
// Return -1 if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
int _GSetGetIndexLast(GSet* that, void* data) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
    // Set a pointer toward the tail of the GSet
    GSetElem* p = that->_tail;
    // Set a variable to memorize index
    int index = that->_nbElem - 1;
    // Loop on elements until we have found the
    // requested data or reached the head of the list
    while (p != NULL && p->_data != data) {

```

```

        --index;
        p = p->_prev;
    }
    // Return the index
    return index;
}

// Function to get the first element of the GSet
// which point to 'data'
// Return NULL if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetFirstElem(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Set a pointer toward the head of the GSet
    GSetElem* p = that->_head;
    // Loop on elements until we have found the
    // requested data or reached the end of the list
    while (p != NULL && p->_data != data)
        p = p->_next;
    // Return the pointer
    return p;
}

// Function to get the last element of the GSet
// which point to 'data'
// Return NULL if 'data' is not in the set
#if BUILDMODE != 0
inline
#endif
GSetElem* _GSetGetLastElem(GSet* that, void* data) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Set a pointer toward the head of the GSet
    GSetElem* p = that->_tail;
    // Loop on elements until we have found the
    // requested data or reached the end of the list
    while (p != NULL && p->_data != data)
        p = p->_prev;
    // Return the pointer
    return p;
}

// Merge the GSet 'set' at the end of the GSet 'that'
// 'that' and 'set' can be empty
// After calling this function 'set' is empty
#if BUILDMODE != 0
inline
#endif
void _GSetMerge(GSet* that, GSet* set) {

```

```

#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PErrCatch(GSetErr);
    }
    if (set == NULL) {
        GSetErr->_type = PErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PErrCatch(GSetErr);
    }
}
#endif
// If 'set' is not empty
if (set->_nbElem != 0) {
    // If 'that' is empty
    if (that->_nbElem == 0) {
        // Copy 'set' into 'that'
        memcpy(that, set, sizeof(GSet));
        // Empty 'set'
        set->_head = NULL;
        set->_tail = NULL;
        set->_nbElem = 0;
    }
    // Else, if 'that' is not empty
} else {
    // Add 'set' to the tail of 'that'
    that->_tail->_next = set->_head;
    // Add 'that' to the head of 'set'
    set->_head->_prev = that->_tail;
    // Update the tail of 'that'
    that->_tail = set->_tail;
    // Update the number of element of 'that'
    that->_nbElem += set->_nbElem;
    // Empty 'set'
    set->_head = NULL;
    set->_tail = NULL;
    set->_nbElem = 0;
}
}
}

// Split the GSet at the GSetElem 'e'
// 'e' must be and element of the set
// the set new end is the element before 'e', the set becomes empty if
// 'e' was the first element
// Return a new GSet starting with 'e', or NULL if 'e' is not
// an element of the set
#if BUILDMODE != 0
inline
#endif
GSet* _GSetSplit(GSet* that, GSetElem* e) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PErrCatch(GSetErr);
        }
        if (e == NULL) {
            GSetErr->_type = PErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'e' is null");
            PErrCatch(GSetErr);
        }
    }
}
#endif

```

```

// Check that e is an element of that
// Declare a variable to count element before e in that
int nb = 0;
// If e is not the head of that
if (that->_head != e) {
    GSetElem* ptr = e;
    // While there is an element before e
    do {
        // Increment the number of element
        ++nb;
        // Move to the previous element
        ptr = ptr->_prev;
    } while (ptr != NULL && ptr != that->_head);
    // If we have reached an element without previous element, this
    // element is not the head of that, meaning e is not in the set
    if (ptr == NULL)
        // Stop here
        return NULL;
}
// Allocate memory for the result
GSet* res = GSetCreate();
// Set the head of res
res->_head = e;
// Set the tail of res
res->_tail = that->_tail;
// Set the number of element of res
res->_nbElem = that->_nbElem - nb;
// Set the tail of s
that->_tail = e->_prev;
// Set the number of element of that
that->_nbElem = nb;
// If that is empty
if (nb == 0)
    // Update head
    that->_head = NULL;
// Else, that is not empty
else
    // Disconnect the tail of that
    that->_tail->_next = NULL;
// Disconnect the head of res
res->_head->_prev = NULL;
// Return the result
return res;
}

// Switch the 'iElem'-th and 'jElem'-th element of the set
#if BUILDMODE != 0
inline
#endif
void _GSetSwitch(GSet* that, int iElem, int jElem) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (iElem < 0 || iElem >= that->_nbElem) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'iElem' is invalid (0<=%d<=%d)",
            iElem, that->_nbElem);
        PBErrCatch(GSetErr);
    }
}

```

```

    if (jElem < 0 || jElem >= that->_nbElem) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'jElem' is invalid (0<=%d<%d)",
            jElem, that->_nbElem);
        PBErrCatch(GSetErr);
    }
#endif
    // Get the two elements
    GSetElem* iPtr = GSetGetElem(that, iElem);
    GSetElem* jPtr = GSetGetElem(that, jElem);
    // Switch the elements
    float v = iPtr->_sortVal;
    iPtr->_sortVal = jPtr->_sortVal;
    jPtr->_sortVal = v;
    void* dat = iPtr->_data;
    iPtr->_data = jPtr->_data;
    jPtr->_data = dat;
}

// Set the sort value of the GSetElem 'that' to 'v'
#if BUILDMODE != 0
inline
#endif
void GSetElemSetSortVal(GSetElem* that, float v) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    that->_sortVal = v;
}

// Create a new GSetIterForward for the GSet 'set'
// The iterator is reset upon creation
#if BUILDMODE != 0
inline
#endif
GSetIterForward _GSetIterForwardCreateStatic(GSet* set) {
#if BUILDMODE == 0
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Create the iterator
    GSetIterForward ret = {._set = set, ._curElem = set->_head};
    // Return the new iterator
    return ret;
}

// Create a new GSetIterBackward for the GSet 'set'
// The iterator is reset upon creation
#if BUILDMODE != 0
inline
#endif
GSetIterBackward _GSetIterBackwardCreateStatic(GSet* set) {
#if BUILDMODE == 0
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
    }
#endif
}

```



```

        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Create the iterator
    GSetIterBackward ret = {._set = set, ._curElem = set->_tail};
    // Return the new iterator
    return ret;
}

// Reset the GSetIterForward to its starting position
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardReset(GSetIterForward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Reset
    that->_curElem = that->_set->_head;
}

// Reset the GSetIterBackward to its starting position
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardReset(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Reset
    that->_curElem = that->_set->_tail;
}

// Step the GSetIterForward
// Return false if arguments are invalid or we couldn't step
// Return true else
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardStep(GSetIterForward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Step
    if (that->_curElem != NULL && that->_curElem->_next != NULL)
        that->_curElem = that->_curElem->_next;
    else

```

```

        return false;
    return true;
}

// Step the GSetIterBackward
// Return false if arguments are invalid or we couldn't step
// Return true else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardStep(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Step
    if (that->_curElem != NULL && that->_curElem->_prev != NULL)
        that->_curElem = that->_curElem->_prev;
    else
        return false;
    return true;
}

// Apply a function to all elements of the GSet of the GSetIterForward
// The iterator is first reset, then the function is apply sequentially
// using the Step function of the iterator
// The applied function takes to void* arguments: 'data' is the _data
// property of the nodes, 'param' is a hook to allow the user to pass
// parameters to the function through a user-defined structure
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardApply(GSetIterForward* that,
    void(*fun)(void* data, void* param), void* param) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (fun == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'fun' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Reset the iterator
    GSetIterReset(that);
    // If the set is not empty
    if (that->_curElem != NULL)
        // Loop on element
        do {
            // Apply the user function
            fun(that->_curElem->_data, param);
        } while (GSetIterStep(that) == true);
}

// Apply a function to all elements of the GSet of the GSetIterBackward
// The iterator is first reset, then the function is apply sequentially

```

```

// using the Step function of the iterator
// The applied function takes to void* arguments: 'data' is the _data
// property of the nodes, 'param' is a hook to allow the user to pass
// parameters to the function through a user-defined structure
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardApply(GSetIterBackward* that,
    void(*fun)(void* data, void* param), void* param) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (fun == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'fun' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Reset the iterator
    GSetIterReset(that);
    // If the set is not empty
    if (that->_curElem != NULL)
        // Loop on element
        do {
            // Apply the user function
            fun(that->_curElem->_data, param);
        } while (GSetIterStep(that) == true);
}

// Return true if the iterator is at the start of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardIsFirst(GSetIterForward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    if (that->_curElem == that->_set->_head)
        return true;
    else
        return false;
}

// Return true if the iterator is at the start of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardIsFirst(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;

```

```

        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    if (that->_curElem == that->_set->_tail)
        return true;
    else
        return false;
}

// Return true if the iterator is at the end of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardIsLast(GSetIterForward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    if (that->_curElem == that->_set->_tail)
        return true;
    else
        return false;
}

// Return true if the iterator is at the end of the elements (from
// its point of view, not the order in the GSet)
// Return false else
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardIsLast(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    if (that->_curElem == that->_set->_head)
        return true;
    else
        return false;
}

// Change the attached set of the iterator, and reset it
#if BUILDMODE != 0
inline
#endif
void GSetIterForwardSetGSet(GSetIterForward* that, GSet* set) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (set == NULL) {

```

```

        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Set the GSet
    that->_set = set;
    // Reset the iterator
    GSetIterReset(that);
}

// Change the attached set of the iterator, and reset it
#if BUILDMODE != 0
inline
#endif
void GSetIterBackwardSetGSet(GSetIterBackward* that, GSet* set) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
        if (set == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'set' is null");
            PBErrCatch(GSetErr);
        }
    #endif
    // Set the GSet
    that->_set = set;
    // Reset the iterator
    GSetIterReset(that);
}

// Return the data currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
void* GSetIterForwardGet(GSetIterForward* that) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
    // Return the data
    return that->_curElem->_data;
}

// Return the data currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
void* GSetIterBackwardGet(GSetIterBackward* that) {
    #if BUILDMODE == 0
        if (that == NULL) {
            GSetErr->_type = PBErrTypeNullPointer;
            sprintf(GSetErr->_msg, "'that' is null");
            PBErrCatch(GSetErr);
        }
    #endif
}

```

```

    // Return the data
    return that->_curElem->_data;
}

// Return the element currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
GSetElem* GSetIterForwardGetElem(GSetIterForward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Return the data
    return that->_curElem;
}

// Return the element currently pointed to by the iterator
#if BUILDMODE != 0
inline
#endif
GSetElem* GSetIterBackwardGetElem(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Return the data
    return that->_curElem;
}

// Return the number of element in the set
#if BUILDMODE != 0
inline
#endif
int _GSetNbElem(GSet* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // Return the data
    return that->_nbElem;
}

// Remove the element currently pointed to by the iterator
// The iterator is moved forward to the next element
// Return false if we couldn't move
// Return true else
// It's the responsibility of the user to delete the content of the
// element prior to calling this function
#if BUILDMODE != 0
inline
#endif
bool GSetIterForwardRemoveElem(GSetIterForward* that) {

```

```

#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    GSetElem *next = that->_curElem->_next;
    GSetRemoveElem(that->_set, &(amp;that->_curElem));
    that->_curElem = next;
    if (next != NULL)
        return true;
    else
        return false;
}

// Remove the element currently pointed to by the iterator
// The iterator is moved backward to the next element
// Return false if we couldn't move
// Return true else
// It's the responsibility of the user to delete the content of the
// element prior to calling this function
#if BUILDMODE != 0
inline
#endif
bool GSetIterBackwardRemoveElem(GSetIterBackward* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
#endif
    GSetElem *prev = that->_curElem->_prev;
    GSetRemoveElem(that->_set, &(amp;that->_curElem));
    that->_curElem = prev;
    if (prev != NULL)
        return true;
    else
        return false;
}

// Append the element of the GSet 'set' at the end of the GSet 'that'
// 'that' and 'set' can be empty
#if BUILDMODE != 0
inline
#endif
void _GSetAppendSet(GSet* that, GSet* set) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
    // If there are elements in the set to append
    if (GSetNbElem(set) > 0) {

```

```

        // Declare an iterator on the set to append
        GSetIterForward iter = GSetIterForwardCreateStatic(set);
        // Loop on element to append
        do {
            // Get the data to append
            void* data = GSetIterGet(&iter);
            // Append the data to the end of the set
            GSetAppend(that, data);
        } while (GSetIterStep(&iter));
    }
}

// Append the element of the GSet 'that' at the end of the GSet 'set'
// Elements are kept sorted
// 'that' and 'set' can be empty
#if BUILDMODE != 0
inline
#endif
void _GSetAppendSortedSet(GSet* that, GSet* set) {
#if BUILDMODE == 0
    if (that == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'that' is null");
        PBErrCatch(GSetErr);
    }
    if (set == NULL) {
        GSetErr->_type = PBErrTypeNullPointer;
        sprintf(GSetErr->_msg, "'set' is null");
        PBErrCatch(GSetErr);
    }
#endif
// If there are elements in the set to append
if (GSetNbElem(set) > 0) {
    // Declare an iterator on the set to append
    GSetIterForward iter = GSetIterForwardCreateStatic(set);
    // Loop on element to append
    do {
        // Get the element to append
        GSetElem* elem = GSetIterGetElem(&iter);
        // Append the data of the element according to the sorting value
        GSetAddSort(that, elem->_data, elem->_sortVal);
    } while (GSetIterStep(&iter));
}
}
}

```

3 Makefile

```

#directory
PBERRDIR=../PBErr

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

include $(PBERRDIR)/Makefile.inc

INCPATH=-I./ -I$(PBERRDIR)/

```



```

BUILDOPTIONS=$(BUILDPARAM) $(INCPATH)

# compiler
COMPILER=gcc

#rules
all : main

main: main.o pberr.o gset.o Makefile
$(COMPILER) main.o pberr.o gset.o $(LINKOPTIONS) -o main

main.o : main.c $(PBERRDIR)/pberr.h gset.h gset-inline.c Makefile
$(COMPILER) $(BUILDOPTIONS) -c main.c

gset.o : gset.c gset.h gset-inline.c Makefile
$(COMPILER) $(BUILDOPTIONS) -c gset.c

pberr.o : $(PBERRDIR)/pberr.c $(PBERRDIR)/pberr.h Makefile
$(COMPILER) $(BUILDOPTIONS) -c $(PBERRDIR)/pberr.c

clean :
rm -rf *.o main

valgrind :
valgrind -v --track-origins=yes --leak-check=full --gen-suppressions=yes --show-leak-kinds=all ./main

unitTest :
main > unitTest.txt; diff unitTest.txt unitTestRef.txt

```

4 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 <math.h>
#include "pberr.h"
#include "gset.h"

#define RANDOMSEED 0
#define rnd() (float)(rand())/(float)(RAND_MAX)

void UnitTestGSetCreateFree() {
    GSet* set = GSetCreate();
    if (set == NULL) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "set is null");
        PBErrCatch(GSetErr);
    }
    if (set->_nbElem != 0) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "_nbElem is invalid (%d==0)", set->_nbElem);
        PBErrCatch(GSetErr);
    }
    if (set->_head != NULL) {

```

```

    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "_head is not null");
    PBErrCatch(GSetErr);
}
if (set->_tail != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "_tail is not null");
    PBErrCatch(GSetErr);
}
GSetFree(&set);
if (set != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "set is not null after free");
    PBErrCatch(GSetErr);
}
set = GSetCreate();
GSetPush(set, NULL);
GSetFree(&set);
if (set != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "set is not null after free");
    PBErrCatch(GSetErr);
}
GSet setstatic = GSetCreateStatic();
if (setstatic._nbElem != 0) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "_nbElem is invalid (%d==0)",
        setstatic._nbElem);
    PBErrCatch(GSetErr);
}
if (setstatic._head != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "_head is not null");
    PBErrCatch(GSetErr);
}
if (setstatic._tail != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "_tail is not null");
    PBErrCatch(GSetErr);
}
printf("UnitTestGSetCreateFree OK\n");
}

void UnitTestGSetClone() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSet* clone = GSetClone(&set);
    if (clone->_nbElem != 5) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetClone NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterForward iter = GSetIterForwardCreateStatic(clone);
    int i = 0;
    do {
        if (a + i != GSetIterGet(&iter)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetClone NOK");
            PBErrCatch(GSetErr);
        }
    }
}

```

```

    ++i;
} while (GSetIterStep(&iter));
GSetFree(&clone);
GSetFlush(&set);
printf("UnitTestGSetClone OK\n");
}

void UnitTestGSetFlush() {
    GSet* set = GSetCreate();
    for (int i = 5; i--;)
        GSetPush(set, NULL);
    GSetFlush(set);
    if (set->_head != NULL) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "_head is not null after flush");
        PBErrCatch(GSetErr);
    }
    if (set->_tail != NULL) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "_tail is not null after flush");
        PBErrCatch(GSetErr);
    }
    if (set->_nbElem != 0) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "_nbElem is not 0 after flush");
        PBErrCatch(GSetErr);
    }
    GSetFree(&set);
    printf("UnitTestGSetFlush OK\n");
}

void printData(void* data, FILE* stream) {
    fprintf(stream, "%d", *(int*)data);
}

void UnitTestGSetPrint() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetPrint(&set, stdout, printData, " ");
    printf("\n");
    GSetFlush(&set);
    printf("UnitTestGSetPrint OK\n");
}

void UnitTestGSetPushPopAppendDrop() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;) {
        GSetPush(&set, a + i);
        GSetPrint(&set, stdout, printData, " ");
        printf("\n");
    }
    if (set._nbElem != 5) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetPushPopAppendDrop NOK");
        PBErrCatch(GSetErr);
    }
    for (int i = 5; i--;) {
        while (GSetPop(&set) == NULL);
        GSetPrint(&set, stdout, printData, " ");
    }
}

```

```

    printf("\n");
}
if (set._nbElem != 0) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetPushPopAppendDrop NOK");
    PBErrCatch(GSetErr);
}
for (int i = 5; i--;) {
    GSetAppend(&set, a + i);
    GSetPrint(&set, stdout, printData, ", ");
    printf("\n");
}
if (set._nbElem != 5) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetPushPopAppendDrop NOK");
    PBErrCatch(GSetErr);
}
for (int i = 5; i--;) {
    while (GSetDrop(&set) == NULL);
    GSetPrint(&set, stdout, printData, ", ");
    printf("\n");
}
if (set._nbElem != 0) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetPushPopAppendDrop NOK");
    PBErrCatch(GSetErr);
}
GSetFlush(&set);
printf("UnitTestGSetPushPopAppendDrop OK\n");
}

void UnitTestGSetAddSort() {
    srandom(RANDOMSEED);
    int a[5] = {-2, -1, 0, 1, 2};
    int nbTest = 1000;
    GSet set = GSetCreateStatic();
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    for (int iTest = nbTest; iTest--;) {
        for (int i = 10; i--;) {
            int j = (int)floor(rnd() * 5);
            GSetAddSort(&set, a + j, a[j]);
        }
        GSetIterReset(&iter);
        int v = *(int*)GSetIterGet(&iter);
        GSetIterStep(&iter);
        do {
            int w = *(int*)GSetIterGet(&iter);
            if (w < v) {
                GSetErr->_type = PBErrTypeUnitTestFailed;
                sprintf(GSetErr->_msg, "GSetAddSort NOK");
                PBErrCatch(GSetErr);
            }
            v = w;
        } while (GSetIterStep(&iter));
        GSetFlush(&set);
    }
    printf("UnitTestGSetAddSort OK\n");
}

void UnitTestGSetInsertRemove() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();

```

```

GSetIterForward iter = GSetIterForwardCreateStatic(&set);
GSetInsert(&set, a, 2);
int *checka[3] = {NULL, NULL, a};
int i = 0;
GSetIterReset(&iter);
do {
    if (checka[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetInsert NOK");
        PErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetFlush(&set);
GSetInsert(&set, a, 0);
GSetInsert(&set, a + 1, 1);
GSetInsert(&set, a + 2, 1);
GSetInsert(&set, a + 3, 1);
GSetInsert(&set, a + 4, 3);
int *checkb[5] = {a, a + 3, a + 2, a + 4, a + 1};
i = 0;
GSetIterReset(&iter);
do {
    if (checkb[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetInsert NOK");
        PErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetRemove(&set, 0);
int *checkc[4] = {a + 3, a + 2, a + 4, a + 1};
i = 0;
GSetIterReset(&iter);
do {
    if (checkc[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetRemove NOK");
        PErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetRemove(&set, 3);
int *checkd[3] = {a + 3, a + 2, a + 4};
i = 0;
GSetIterReset(&iter);
do {
    if (checkd[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetRemove NOK");
        PErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetRemove(&set, 1);
int *checke[2] = {a + 3, a + 4};
i = 0;
GSetIterReset(&iter);
do {
    if (checke[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetRemove NOK");
    }
    ++i;
} while (GSetIterStep(&iter));

```

```

        PBErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetRemove(&set, 1);
int *checkf[1] = {a + 3};
i = 0;
GSetIterReset(&iter);
do {
    if (checkf[i] != GSetIterGet(&iter)) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetRemove NOK");
        PBErrCatch(GSetErr);
    }
    ++i;
} while (GSetIterStep(&iter));
GSetRemove(&set, 0);
if (set._nbElem != 0 || set._head != NULL || set._tail != NULL) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "GSetRemove NOK");
    PBErrCatch(GSetErr);
}
printf("UnitTestGSetInsertRemove OK\n");
}

void UnitTestGSetNbElemGet() {
    int a[5] = {0, 1, 2, 3, 4};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;) {
        GSetPush(&set, a + i);
        if (5 - i != GSetNbElem(&set)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetNbElem NOK");
            PBErrCatch(GSetErr);
        }
    }
    for (int i = 5; i--;)
        if (i != *(int*)GSetGet(&set, i)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetGet NOK");
            PBErrCatch(GSetErr);
        }
    GSetFlush(&set);
    printf("UnitTestGSetNbElemGet OK\n");
}

void UnitTestGSetGetIndex() {
    int a[5] = {0, 1, 2, 3, 4};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    for (int i = 5; i--;)
        GSetAppend(&set, a + i);
    for (int i = 5; i--;) {
        if (i != GSetGetIndexFirst(&set, a + i)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetGetIndexFirst NOK");
            PBErrCatch(GSetErr);
        }
        if (9 - i != GSetGetIndexLast(&set, a + i)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetGetIndexLast NOK");
        }
    }
}

```

```

        PBErrCatch(GSetErr);
    }
}
GSetFlush(&set);
printf("UnitTestGSetGetIndex OK\n");
}

void UnitTestGSetSort() {
    srandom(RANDOMSEED);
    int a[5] = {-2, -1, 0, 1, 2};
    int nbTest = 1000;
    GSet set = GSetCreateStatic();
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    for (int iTest = nbTest; iTest--;) {
        for (int i = 10; i--;) {
            int j = (int)floor(rnd() * 5);
            GSetPush(&set, a + j);
            GSetElemSetSortVal(GSetGetElem(&set, 0), a[j]);
        }
        GSetSort(&set);
        GSetIterReset(&iter);
        int v = *(int*)GSetIterGet(&iter);
        GSetIterStep(&iter);
        do {
            int w = *(int*)GSetIterGet(&iter);
            if (w < v) {
                GSetErr->_type = PBErrTypeUnitTestFailed;
                sprintf(GSetErr->_msg, "GSetSort NOK");
                PBErrCatch(GSetErr);
            }
            v = w;
        } while (GSetIterStep(&iter));
        GSetFlush(&set);
    }
    printf("UnitTestGSetSort OK\n");
}

void UnitTestGSetSplitMerge() {
    int a[5] = {0, 1, 2, 3, 4};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    for (int i = 5; i--;)
        GSetAppend(&set, a + i);
    GSet* split = GSetSplit(&set, GSetGetElem(&set, 5));
    if (split->_nbElem != 5 || set._nbElem != 5) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetSplit NOK");
        PBErrCatch(GSetErr);
    }
    for (int i = 5; i--;) {
        if (a[i] != *(int*)GSetGet(&set, i)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetSplit NOK");
            PBErrCatch(GSetErr);
        }
    }
    if (a[i] != *(int*)GSetGet(split, 4 - i)) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetSplit NOK");
        PBErrCatch(GSetErr);
    }
}
}

```

```

GSetMerge(&set, split);
if (split->_nbElem != 0 || set._nbElem != 10) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "GSetMerge NOK");
    PBErrCatch(GSetErr);
}
for (int i = 5; i--;) {
    if (i != GSetGetIndexFirst(&set, a + i)) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetMerge NOK");
        PBErrCatch(GSetErr);
    }
    if (9 - i != GSetGetIndexLast(&set, a + i)) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetMerge NOK");
        PBErrCatch(GSetErr);
    }
}
GSetFlush(&set);
GSetFree(&split);
printf("UnitTestGSetSplitMerge OK\n");
}

void UnitTestGSetSwitch() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetSwitch(&set, 0, 4);
    GSetSwitch(&set, 1, 3);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    int *checka[5] = {a + 4, a + 3, a + 2, a + 1, a};
    int i = 0;
    GSetIterReset(&iter);
    do {
        if (checka[i] != GSetIterGet(&iter)) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetSwitch NOK");
            PBErrCatch(GSetErr);
        }
        ++i;
    } while (GSetIterStep(&iter));
    GSetFlush(&set);
    printf("UnitTestGSetSwitch OK\n");
}

void UnitTestGSetMoveElem() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetMoveElem(&set, 3, 1);
    int checka[5] = {1, 4, 2, 3, 5};
    for (int i = 5; i--;) {
        if (checka[i] != *((int*)GSetGet(&set, i))) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetMoveElem NOK");
            PBErrCatch(GSetErr);
        }
    }
    GSetMoveElem(&set, 1, 3);
    int checkb[5] = {1, 2, 3, 4, 5};

```



```

for (int i = 5; i--;) {
    if (checkb[i] != *((int*)GSetGet(&set, i))) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetMoveElem NOK");
        PBErrCatch(GSetErr);
    }
}
GSetMoveElem(&set, 0, 3);
int checkc[5] = {2, 3, 4, 1, 5};
for (int i = 5; i--;) {
    if (checkc[i] != *((int*)GSetGet(&set, i))) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetMoveElem NOK");
        PBErrCatch(GSetErr);
    }
}
GSetMoveElem(&set, 4, 1);
int checkd[5] = {2, 5, 3, 4, 1};
for (int i = 5; i--;) {
    if (checkd[i] != *((int*)GSetGet(&set, i))) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "GSetMoveElem NOK");
        PBErrCatch(GSetErr);
    }
}
GSetFlush(&set);
printf("UnitTestGSetMoveElem OK\n");
}

void UnitTestGSetMergeSet() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet setA = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&setA, a + i);
    GSet setB = GSetCreateStatic();
    for (int i = 2; i--;)
        GSetPush(&setB, a + i + 3);
    GSetAppendSet(&setA, &setB);
    for (int i = 5; i--;) {
        if (a[i] != *((int*)GSetGet(&setA, i))) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetAppendSet NOK");
            PBErrCatch(GSetErr);
        }
    }
    GSetFlush(&setA);
    GSetFlush(&setB);
    for (int i = 3; i--;)
        GSetAddSort(&setB, a + i, i);
    for (int i = 2; i--;)
        GSetAddSort(&setA, a + i + 3, i + 3);
    GSetAppendSortedSet(&setA, &setB);
    for (int i = 5; i--;) {
        if (a[i] != *((int*)GSetGet(&setA, i))) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "GSetAppendSortedSet NOK");
            PBErrCatch(GSetErr);
        }
    }
    GSetFlush(&setA);
    GSetFlush(&setB);
    printf("UnitTestGSetMergeSet OK\n");
}

```

```

}

void UnitTestGSet() {
    UnitTestGSetCreateFree();
    UnitTestGSetClone();
    UnitTestGSetFlush();
    UnitTestGSetPrint();
    UnitTestGSetPushPopAppendDrop();
    UnitTestGSetAddSort();
    UnitTestGSetInsertRemove();
    UnitTestGSetNbElemGet();
    UnitTestGSetGetIndex();
    UnitTestGSetSort();
    UnitTestGSetSplitMerge();
    UnitTestGSetSwitch();
    UnitTestGSetMoveElem();
    UnitTestGSetMergeSet();
    printf("UnitTestGSet OK\n");
}

void UnitTestGSetIteratorForwardCreateFree() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterForward* iter = GSetIterForwardCreate(&set);
    if (iter->_set != &set || iter->_curElem != set._head) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardCreateFree NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterFree(&iter);
    if (iter != NULL) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "iter is not NULL after free");
        PBErrCatch(GSetErr);
    }
    GSetIterForward iterb = GSetIterForwardCreateStatic(&set);
    if (iterb._set != &set || iterb._curElem != set._head) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardCreateFree NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorForwardCreateFree OK\n");
}

void UnitTestGSetIteratorForwardClone() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    GSetIterForward* iterb = GSetIterClone(&iter);
    if (iter._set != iterb->_set || iter._curElem != iterb->_curElem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardClone NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterFree(&iterb);
    GSetFlush(&set);
    printf("UnitTestGSetIteratorForwardClone OK\n");
}

```

```

}

void UnitTestGSetIteratorForwardReset() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    GSetIterStep(&iter);
    GSetIterReset(&iter);
    if (iter._curElem != set._head) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardReset NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorForwardReset OK\n");
}

void UnitTestGSetIteratorForwardStepGetGetElem() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    GSetElem* elem = set._head->_next;
    GSetIterStep(&iter);
    if (iter._curElem != elem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardStepGetGetElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetIterGetElem(&iter) != elem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardStepGetGetElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetIterGet(&iter) != a + 1) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardStepGetGetElem NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorForwardStepGetGetElem OK\n");
}

void FunInc(void* data, void* param) {
    while (param != param);
    ++(*(int*)data);
}

void UnitTestGSetIteratorForwardApply() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    GSetIterApply(&iter, &FunInc, NULL);
    for (int i = 5; i--;)

```

```

        if (a[i] != i + 2) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardApply NOK");
            PBErrCatch(GSetErr);
        }
        GSetFlush(&set);
        printf("UnitTestGSetIteratorForwardApply OK\n");
    }

void UnitTestGSetIteratorForwardIsFirstIsLast() {
    int a[3] = {1, 2, 3};
    GSet set = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&set, a + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    if (GSetIterIsFirst(&iter) == false || GSetIterIsLast(&iter) == true) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterStep(&iter);
    if (GSetIterIsFirst(&iter) == true || GSetIterIsLast(&iter) == true) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterStep(&iter);
    if (GSetIterIsFirst(&iter) == true || GSetIterIsLast(&iter) == false) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorForwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorForwardIsFirstIsLast OK\n");
}

void UnitTestGSetIteratorForwardSetGSet() {
    int a[3] = {1, 2, 3};
    GSet set = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&set, a + i);
    int b[3] = {1, 2, 3};
    GSet setb = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&setb, b + i);
    GSetIterForward iter = GSetIterForwardCreateStatic(&set);
    GSetIterSetGSet(&iter, &setb);
    if (iter._set != &setb || iter._curElem != setb._head) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardSetGSet NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    GSetFlush(&setb);
    printf("UnitTestGSetIteratorForwardSetGSet OK\n");
}

void UnitTestGSetIteratorForwardRemoveElem() {
    int a[3] = {1, 2, 3};

```

```

GSet set = GSetCreateStatic();
for (int i = 3; i--;)
    GSetPush(&set, a + i);
GSetIterForward iter = GSetIterForwardCreateStatic(&set);
GSetIterStep(&iter);
if (GSetIterRemoveElem(&iter) == false) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardRemoveElem NOK");
    PBErrCatch(GSetErr);
}
if (GSetNbElem(&set) != 2) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardRemoveElem NOK");
    PBErrCatch(GSetErr);
}
if (iter._curElem != set._head->_next) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardRemoveElem NOK");
    PBErrCatch(GSetErr);
}
if (GSetIterRemoveElem(&iter) == true) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardRemoveElem NOK");
    PBErrCatch(GSetErr);
}
if (GSetNbElem(&set) != 1) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorForwardRemoveElem NOK");
    PBErrCatch(GSetErr);
}
GSetFlush(&set);
printf("UnitTestGSetIteratorForwardRemoveElem OK\n");
}

void UnitTestGSetIteratorForward() {
    UnitTestGSetIteratorForwardCreateFree();
    UnitTestGSetIteratorForwardClone();
    UnitTestGSetIteratorForwardReset();
    UnitTestGSetIteratorForwardStepGetGetElem();
    UnitTestGSetIteratorForwardApply();
    UnitTestGSetIteratorForwardIsFirstIsLast();
    UnitTestGSetIteratorForwardSetGSet();
    UnitTestGSetIteratorForwardRemoveElem();
    printf("UnitTestGSetIteratorForward OK\n");
}

void UnitTestGSetIteratorBackwardCreateFree() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward* iter = GSetIterBackwardCreate(&set);
    if (iter->_set != &set || iter->_curElem != set._tail) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardCreateFree NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterFree(&iter);
    if (iter != NULL) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "iter is not NULL after free");
        PBErrCatch(GSetErr);
    }
}

```

```

    }
    GSetIterBackward iterb = GSetIterBackwardCreateStatic(&set);
    if (iterb._set != &set || iterb._curElem != set._tail) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardCreateFree NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardCreateFree OK\n");
}

void UnitTestGSetIteratorBackwardClone() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    GSetIterBackward* iterb = GSetIterClone(&iter);
    if (iter._set != iterb->_set || iter._curElem != iterb->_curElem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardClone NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterFree(&iterb);
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardClone OK\n");
}

void UnitTestGSetIteratorBackwardReset() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    GSetIterStep(&iter);
    GSetIterReset(&iter);
    if (iter._curElem != set._tail) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardReset NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardReset OK\n");
}

void UnitTestGSetIteratorBackwardStepGetGetElem() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    GSetElem* elem = set._tail->_prev;
    GSetIterStep(&iter);
    if (iter._curElem != elem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorBackwardStepGetGetElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetIterGetElem(&iter) != elem) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,

```

```

        "UnitTestGSetIteratorBackwardStepGetGetElem NOK");
    PBErrCatch(GSetErr);
}
if (GSetIterGet(&iter) != a + 3) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg,
        "UnitTestGSetIteratorBackwardStepGetGetElem NOK");
    PBErrCatch(GSetErr);
}
GSetFlush(&set);
printf("UnitTestGSetIteratorBackwardStepGetGetElem OK\n");
}

void UnitTestGSetIteratorBackwardApply() {
    int a[5] = {1, 2, 3, 4, 5};
    GSet set = GSetCreateStatic();
    for (int i = 5; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    GSetIterApply(&iter, &FunInc, NULL);
    for (int i = 5; i--;)
        if (a[i] != i + 2) {
            GSetErr->_type = PBErrTypeUnitTestFailed;
            sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardApply NOK");
            PBErrCatch(GSetErr);
        }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardApply OK\n");
}

void UnitTestGSetIteratorBackwardIsFirstIsLast() {
    int a[3] = {1, 2, 3};
    GSet set = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    if (GSetIterIsFirst(&iter) == false || GSetIterIsLast(&iter) == true) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorBackwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterStep(&iter);
    if (GSetIterIsFirst(&iter) == true || GSetIterIsLast(&iter) == true) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorBackwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetIterStep(&iter);
    if (GSetIterIsFirst(&iter) == true || GSetIterIsLast(&iter) == false) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg,
            "UnitTestGSetIteratorBackwardIsFirstIsLast NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardIsFirstIsLast OK\n");
}

void UnitTestGSetIteratorBackwardSetGSet() {
    int a[3] = {1, 2, 3};

```

```

GSet set = GSetCreateStatic();
for (int i = 3; i--;)
    GSetPush(&set, a + i);
int b[3] = {1, 2, 3};
GSet setb = GSetCreateStatic();
for (int i = 3; i--;)
    GSetPush(&setb, b + i);
GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
GSetIterSetGSet(&iter, &setb);
if (iter._set != &setb || iter._curElem != setb._tail) {
    GSetErr->_type = PBErrTypeUnitTestFailed;
    sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardSetGSet NOK");
    PBErrCatch(GSetErr);
}
GSetFlush(&set);
GSetFlush(&setb);
printf("UnitTestGSetIteratorBackwardSetGSet OK\n");
}

void UnitTestGSetIteratorBackwardRemoveElem() {
    int a[3] = {1, 2, 3};
    GSet set = GSetCreateStatic();
    for (int i = 3; i--;)
        GSetPush(&set, a + i);
    GSetIterBackward iter = GSetIterBackwardCreateStatic(&set);
    GSetIterStep(&iter);
    if (GSetIterRemoveElem(&iter) == false) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardRemoveElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetNbElem(&set) != 2) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardRemoveElem NOK");
        PBErrCatch(GSetErr);
    }
    if (iter._curElem != set._head) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardRemoveElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetIterRemoveElem(&iter) == true) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardRemoveElem NOK");
        PBErrCatch(GSetErr);
    }
    if (GSetNbElem(&set) != 1) {
        GSetErr->_type = PBErrTypeUnitTestFailed;
        sprintf(GSetErr->_msg, "UnitTestGSetIteratorBackwardRemoveElem NOK");
        PBErrCatch(GSetErr);
    }
    GSetFlush(&set);
    printf("UnitTestGSetIteratorBackwardRemoveElem OK\n");
}

void UnitTestGSetIteratorBackward() {
    UnitTestGSetIteratorBackwardCreateFree();
    UnitTestGSetIteratorBackwardClone();
    UnitTestGSetIteratorBackwardReset();
    UnitTestGSetIteratorBackwardStepGetGetElem();
    UnitTestGSetIteratorBackwardApply();
    UnitTestGSetIteratorBackwardIsFirstIsLast();
}

```



```

    UnitTestGSetIteratorBackwardSetGSet();
    printf("UnitTestGSetIteratorBackward OK\n");
}

void UnitTestAll() {
    UnitTestGSet();
    UnitTestGSetIteratorForward();
    UnitTestGSetIteratorBackward();
    printf("UnitTestAll OK\n");
}

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

```

5 Unit tests output

```

UnitTestGSetCreateFree OK
UnitTestGSetClone OK
UnitTestGSetFlush OK
1, 2, 3, 4, 5
UnitTestGSetPrint OK
5
4, 5
3, 4, 5
2, 3, 4, 5
1, 2, 3, 4, 5
2, 3, 4, 5
3, 4, 5
4, 5
5

5
5, 4
5, 4, 3
5, 4, 3, 2
5, 4, 3, 2, 1
5, 4, 3, 2
5, 4, 3
5, 4
5

UnitTestGSetPushPopAppendDrop OK
UnitTestGSetAddSort OK
UnitTestGSetInsertRemove OK
UnitTestGSetNbElemGet OK
UnitTestGSetGetIndex OK
UnitTestGSetSort OK
UnitTestGSetSplitMerge OK
UnitTestGSetSwitch OK
UnitTestGSetMoveElem OK
UnitTestGSetMergeSet OK
UnitTestGSet OK
UnitTestGSetIteratorForwardCreateFree OK
UnitTestGSetIteratorForwardClone OK
UnitTestGSetIteratorForwardReset OK

```

```
UnitTestGSetIteratorForwardStepGetGetElem OK
UnitTestGSetIteratorForwardApply OK
UnitTestGSetIteratorForwardIsFirstIsLast OK
UnitTestGSetIteratorForwardSetGSet OK
UnitTestGSetIteratorForwardRemoveElem OK
UnitTestGSetIteratorForward OK
UnitTestGSetIteratorBackwardCreateFree OK
UnitTestGSetIteratorBackwardClone OK
UnitTestGSetIteratorBackwardReset OK
UnitTestGSetIteratorBackwardStepGetGetElem OK
UnitTestGSetIteratorBackwardApply OK
UnitTestGSetIteratorBackwardIsFirstIsLast OK
UnitTestGSetIteratorBackwardSetGSet OK
UnitTestGSetIteratorBackward OK
UnitTestAll OK
```