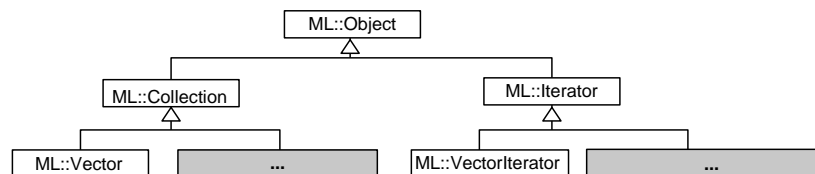


| | | |
|--|---------------------------|--|
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MiniLib

Studieren Sie die abstrakten Basisklassen *ML::Collection* und *ML::Iterator*. Derzeit gibt es zwei davon abgeleitete konkrete Klassen *ML::Vector* und *ML::VectorIterator*, die im Wesentlichen ein dynamisches Feld realisieren. Die Klassenhierarchie hat derzeit somit folgendes Aussehen:



1. Objektmengen (sets)

(12 Punkte)

Realisieren Sie auf Basis der beiden Klassen *ML::Collection* und *ML::Iterator* zwei neue Klassen zur Repräsentation von Mengen (engl. *sets*): Entwerfen Sie eine Klasse *Set* und eine Klasse *SetIterator*. Die Klasse *Set* soll Mengen von Objekten verwalten können. Wie bei Mengen üblich, darf kein Objekt mehrmals in einem *Set* vorkommen. Überlegen Sie, welche Methoden notwendig sind, und vergessen Sie dabei nicht, auch Methoden zur Bildung der Schnittmenge, der Vereinigung und der Differenz zweier Mengen zu realisieren. Die Klasse *SetIterator* soll das "Iterieren" über die Elemente eines *Sets* ermöglichen.

Können Sie die Klassen implementieren ohne Änderungen an der MiniLib vorzunehmen? Wenn nein, welche Änderungen sind notwendig?

Dokumentieren Sie Ihren Entwurf, und zeigen Sie auf, welche Möglichkeiten sich Ihnen geboten haben, und warum Sie sich für die von Ihnen gewählte entschieden haben.

Implementieren Sie die entworfenen Klassen mit allen Methoden und testen Sie diese ausführlich. Wenn Sie Änderungen an der MiniLib vornehmen mussten, geben Sie bitte nur die geänderten Teile ab und heben Sie die Änderungen im Ausdruck hervor (unterstreichen, Leuchtmaker, ...).

2. Objektbehälter (bags)

(12 Punkte)

Entwerfen Sie eine neuerliche Erweiterung der MiniLib zur Repräsentation eines allgemeinen "Objektbehälters" (engl. *bag*). Eine neue Klasse *Bag* (gemeinsam mit einer neuen Iteratorklasse *BagIterator*) soll eine Sammlung von Objekten realisieren, auf welche die gleichen Operationen wie für *Sets* anwendbar sind. Objekte der Klasse *Bag* unterscheiden sich aber von Objekten der Klasse *Set* darin, dass in *Bags* Objekte mehrmals vorkommen dürfen. Implementieren Sie die von Ihnen entworfenen Klassen und achten Sie dabei auf eine möglichst platzsparende Speicherung von mehrfach vorkommenden Objekten. Vergessen Sie nicht, Ihre Entwurfsentscheidungen, eventuelle Probleme und Einschränkungen zu dokumentieren. Testen Sie Ihre Erweiterungen der Klassenbibliothek.

1 Allgemein

Folgend ist die allgemeine Dokumentation angeführt, die beide Aufgabenstellungen betrifft.

Auch bei dieser Übung soll wieder das Testframework CUTE, BOOST verwendet werden um die Implementierung der Tests zu erleichtern und die zur Verfügung gestellten ASSERT Methoden Gebrauch machen zu können.

Auch diesmal soll das Projekt so aufbereitet werden, sodass alle Abhängigkeiten vorhanden sind und die Tests einfach gestartet werden können, ohne zusätzlichen Aufwand.

1.1 Implementierung

Folgen sind die allgemeinen Implementierungen angeführt.

1.1.1 TestsuiteRunner.cpp

Folgend ist die Implementierung des Testsuite Runner angeführt, der alle Tests sammelt und die Tests durchführt.

```
/*
 * main.cpp
 * This is the main for all of the test suites.
 *
 * Created on: Jan 17, 2015
 * Author: Thomas Herzog
 */
#include "SetTest.h"
#include "BagTest.h"
#include "ide_listener.h"
#include "xml_listener.h"
#include "cute_runner.h"

using namespace std;
using namespace ML;
using namespace cute;

static void runSuite(int argc, char const *argv[]) {
    suite setTestSuite, bagTestSuite;
    xml_file_opener xmlfile(argc, argv);
    xml_listener<ide_listener<> > lis(xmlfile.out);

    setTestSuite = makeSetTestSuite();
    bagTestSuite = makeBagTestSuite();
    setTestSuite.insert(setTestSuite.end(), bagTestSuite.begin(),
        bagTestSuite.end());
    makeRunner(lis, argc, argv)(setTestSuite, "AllTests");

    WriteMetaInfo();
}

int main(int argc, char const *argv[]) {
    runSuite(argc, argv);
}
```

2 Objektmengen (Sets)

Folgend ist die Dokumentation für die Aufgabenstellung Set angeführt.

2.1 Lösungsidee

Da bereits in der Übung eine Liste implementiert wurde und diese sich nur durch die Eigenschaft dass sie Duplikate erlaubt von einem Set unterscheidet, soll diese Implementierung wiederverwendet werden, wobei eine Prüfung auf Duplikate erfolgen soll.

Wird versucht Duplikate einzufügen soll diese verhindert werden und eine dementsprechende Meldung auf die Konsole ausgegeben werden.

Da von der bereits implementierten Klasse List abgeleitet werden soll, sind auch keine Änderungen an den Klassen der MiniLib notwendig.

Da die Klasse List bereits eine Iterator Implementierung zur Verfügung stellt und diese alle notwendigen Operationen zur Verfügung stellt, mit den verwendeten Node Typen arbeiten kann, sowie mit dessen Variationen, gibt es keine Notwendigkeit einen neuen Iterator für den Set Container zu implementieren. Sollte dies vielleicht in weiterer Folge erforderlich sein, so kann leicht ein eigener Iterator hinzugefügt werden und die Methode NewIterator der Klasse List überschrieben werden.

Bei der Verwendung des Iterators soll darauf geachtet werden das gegen die Superklasse gearbeitet wird und nicht gegen die eigene Iterator Implementierung, es sei denn man benötigt zusätzliche Funktionalität, die nicht in der Klasse Iterator spezifiziert ist.

Da nur die Prüfungen auf Duplikate erfolgen müssen sollte die Implementierung des Set Containers trivial sein.

Die Mengenoperationen sollen so implementiert werden, dass diese sich wie in der Mathematik spezifiziert verhalten. Lediglich die Spezifikation welches Set die Source und welches Set den Target darstellt wird im Folgenden nach der Erklärung der möglichen Implementierungen der Mengenoperationen definiert.

Die Methoden Intersect(Schnittmenge), Union(Vereinigung) und Complement(A ohne B) könnten wie folgt implementiert werden.

1. `void target->Intersect(Set* source)`

Die Instanz über die die Methode aufgerufen wird spiegelt das Resultat der Operation wieder

2. `void source->Intersect(Set* target)`

Die übergebene Set Instanz spiegelt das Resultat der Operation wieder.

3. `Set* util->(Set* source, Set* target)`

Es wird ein neues Set erstellt, welches das Resultat der Operation widerspiegelt.

Ich würde die Version 3 bevorzugen, jedoch folgt diese Version nicht der Anforderung.

Daher soll Version 1 implementiert werden.

2.2 Implementierung

Folgend sind die Implementierungen für die erste Aufgabenstellung angeführt.

2.2.1 List.h

Folgend ist die Spezifikation des List Containers angeführt.

```

/*
 * List.h
 * This is the implementation of the List container specification.
 *
 * Created on: Jan 17, 2015
 * Author: Thomas Herzog
 */

#ifndef LIST_H_
#define LIST_H_

#include <ostream>
#include "MLCollection.h"
#include "MLObject.h"
#include "Node.h"

/**
 * This is a list container which allows to manage nodes in a double connected list with
 * anchor structure.
 * This structure was chosen because we want to avoid special cases.
 * No it is simple to append and prepend values since it is always the same an null values
 * cannot occur.
 */
class List: public ML::Collection {
protected:
    /**
     * The anchor holding the list elements
     */
    Node* anchor;

    /**
     * The size of this list = node count
     */
    int size;
    /**
     * Finds a value in this list.
     *
     * @param:
     *     object: the value wrapped by a managed node
     * @return:
     *     the found node, nullptr otherwise
     */
    virtual Node* Find(ML::Object* object) const;

public:
    // #####
    // Constructor and destructor
    // #####
    /**
     * This constructor creates an anchor element needed by the double connected list with
     * anchor element.
     * This anchor is initialized properly.
     */
    List();

    /**
     * This destructor clears the list and deletes the anchor element.
     */
    ~List();

    // #####
    // Collection manipulation
    // #####
    /**
     * Adds a item to the list.
     * The item is wrapped into a node.

```

```

    * Default behavior is to prepend the item to the list.
    *
    * @param:
    *     object: the value to be added to the list with a wrapping node instance
    */
virtual void Add(ML::Object* object);

/**
 * Prepends a value to the start of the list by wrapping it into a node instance.
 *
 * @param
 *     object: the object to be prepended to the list via a wrapping node instance
 */
virtual void Prepend(ML::Object* object);

/**
 * Appends a value to the end of the list by wrapping it into a node instance.
 *
 * @param
 *     object: the object to be appended to the list via wrapping node instance
 */
virtual void Append(ML::Object* object);

/**
 * Removes the item from the list.
 * The wrapped value is not deleted but the wrapping node is.
 *
 * @param:
 *     object: the item to be removed from the list
 * @return:
 *     the removed object, nullptr if the object is not managed by this list
 */
ML::Object* Remove(ML::Object* object);

/**
 * Clears the list by removing all nodes from the list.
 * The node instances will be deleted but not the wrapped values.
 * The caller is responsible for the lifecycle of the managed values.
 * The anchor will remain as it is.
 */
void Clear();

// #####
// Utils
// #####
/**
 * Answers the question if the given value is managed by this list.
 *
 * @param:
 *     object: the value to be checked if managed by this list.
 * @return:
 *     true if the value is managed by this list, false otherwise
 */
bool Contains(ML::Object* object) const;

/**
 * Creates a new iterator which allows to iterate over the list
 * starting from the first node.
 *
 * @return:
 *     the iterator for this list
 */
ML::Iterator* NewIterator() const;

/**
 * Prints this list and its managed nodes to the ostream instance.
 *
 * @param:
 *     ostream: the ostream to append the resulting print on
 */
void Print(std::ostream & os) const;

// #####
// Getter and setter
// #####
/**

```

```

    * Returns the current size of this list = node count
    *
    * @return:
    *     the current node count
    */
    int Size() const;

    // #####
    // operator
    // #####
    /**
    * operator for this implementation which calls the Print Method on the given list.
    *
    * @param:
    *     ostream: the ostream to append result print on
    * @param:
    *     list: the list to print out
    * @return:
    *     the ostream with appended print result
    */
    friend std::ostream & operator<<(std::ostream & os, const List & list);
};

/**
 * This is the list iterator which allows to iterate over a list instance.
 */
class ListIterator: public ML::Iterator {

    /**
    * Crates a new iterator for a list.
    *
    * @return:
    *     the iterator instance for this list
    */
    friend ML::Iterator* List::NewIterator() const;

private:
    /**
    * The pointer to current visited node.
    */
    Node* current;
    /**
    * The anchor node of the list
    */
    Node* anchorNode;

    // #####
    // Constructor
    // #####
    /**
    * Private constructor because it is not allowed to instantiate a list iterator
    * outside the list implementation.
    *
    * @param:
    *     anchor: the anchor node
    * @param:
    *     start: the start node of the list
    */
    ListIterator(Node* anchorNode, Node* start);

public:
    // #####
    // Destructor
    // #####
    /**
    * Destructor which does nothing because nodes values are managed by the list only.
    */
    ~ListIterator();

    // #####
    // Utils
    // #####
    /**
    * Returns the next element of the managed list.
    *
    * @return:

```

```

        *           the next node nullptr otherwise
        */
        ML::Object *Next();
};

#endif /* LIST_H_ */

```

2.2.2 List.cpp

Folgend ist die Implementierung der Spezifikation List.h angeführt.

```

/*
 * List.cpp
 * This is the implementation of the List container specification.
 *
 * Created on: Jan 17, 2015
 * Author: Thomas Herzog
 */
#include "List.h"
#include <string>
#include <cassert>

using namespace ML;
using namespace std;

List::List() :
    size(0) {
    Register("List", "Collection");
    /* init anchor properly */
    Node* node = new Node();
    node->next = node;
    node->prev = node;
    anchor = node;
} /* List::List */

List::~List() {
    Clear();
    delete anchor;
} /* List::~List */

int List::Size() const {
    return size;
} /* List::Size */

void List::Add(Object* object) {
    Append(object);
} /* List::Add */

bool List::Contains(Object* object) const {
    return Find(object) != nullptr;
} /* List::Contains */

Object* List::Remove(Object* object) {
    Object* value = nullptr;
    Node* foundNode = Find(object);
    if (foundNode != nullptr) {
        foundNode->prev->next = foundNode->next;
        foundNode->next->prev = foundNode->prev;
        value = foundNode->val;
        delete foundNode;
        size--;
    } /* if */
    return value;
} /* List::Remove */

void List::Clear() {
    Node* next = nullptr;
    Node* node = anchor->next;
    while (node != anchor) {
        next = node->next;
        delete node;
        node = next;
    } /* if */
    anchor->next = anchor;
}

```

```

    anchor->prev = anchor;
    size = 0;
} /* List::Clear */

Iterator* List::NewIterator() const {
    return new ListIterator(anchor, anchor->next);
} /* List::NewIterator */

Node* List::Find(Object* object) const {
    Node* node = anchor->next;
    while ((node != anchor) && (!node->val->IsEqualTo(object))) {
        node = node->next;
    } /* while */
    return ((node != anchor) ? node : nullptr);
} /* List::Find */

void List::Prepend(Object* object) {
    Node* newNode = new Node(object, anchor->prev,
        anchor->prev->next);
    anchor->prev = newNode;
    newNode->prev->next = newNode;
    size++;
} /* List::Prepend */

void List::Append(Object* object) {
    Node* newNode = new Node(object, anchor->next->prev,
        anchor->next);
    anchor->next = newNode;
    newNode->next->prev = newNode;
    size++;
} /* List::Append */

void List::Print(ostream & os) const {
    os << "-----" << endl << Class() << "(" << size << ")" << endl
        << "-----" << endl;
    Node* node = anchor->next;
    while (node != anchor) {
        os << node->AsString();
        node = node->next;
        if (node != anchor) {
            os << ", ";
        } /* if */
    } /* while */
} /* List::Print */

ostream& operator<<(ostream & os, const List & list) {
    list.Print(os);
    return os;
} /* operator<< */

// #####
// Iterator implementation
// #####
ListIterator::ListIterator(Node* anchorNode, Node* start) :
    anchorNode(anchorNode), current(start) {
    Register("ListIterator", "Iterator");
} /* ListIterator::ListIterator */

ListIterator::~ListIterator() {
    // do nothing. current Node lifecycle managed by list not iterator
} /* ListIterator::~ListIterator */

Object* ListIterator::Next() {
    Object* object = nullptr;
    if (current != anchorNode) {
        object = current->val;
        current = current->next;
    } /* if */
    return object;
} /* ListIterator::Next */

```


2.2.3 Node.h

Folgend ist die Spezifikation der Container Node angeführt.

```

/*
 * Node.h
 * This is the specification of the container Node.
 *
 * Created on: Jan 17, 2015
 * Author: Thomas Herzog
 */

#ifndef NODE_H
#define NODE_H

#include <string>
#include "MLObject.h"

/**
 * This class is used to wrap a value into a node instance to be able to manage values with a
 * container implementation.
 */
class Node: public ML::Object {
public:
    /**
     * The wrapped value
     */
    ML::Object* val;
    /**
     * The pointer to the previous node
     */
    Node* prev;
    /**
     * The pointer to the next node
     */
    Node* next;

    // #####
    // Constructor and destructor
    // #####
    /**
     * Constructor which realizes null values for not defined formal parameters.
     *
     * @param:
     *     val: the to wrap value (default nullptr)
     * @param:
     *     prev: the reference to the previous node (default nullptr)
     * @param:
     *     next: the reference to the next node (default nullptr)
     */
    explicit Node(ML::Object* val = nullptr, Node* prev = nullptr,
                  Node* next = nullptr);

    /**
     * This destructor does nothing because values are managed by this node for container
     * usage only.
     * The lifecycle of the values is managed by the caller not the node or the container
     */
    virtual ~Node();

    // #####
    // Utils
    // #####
    /**
     * Returns a string representation of this node and its value.
     *
     * @return:
     *     the string representation of this node
     */
    virtual std::string AsString() const;
};

#endif /* NODE_H */

```

2.2.4 Node.cpp

Folgend ist die Implementierung der Spezifikation Node.h angeführt.

```
/*
 * Node.cpp
 * This is the implementation of the container Node specification.
 *
 * Created on: Jan 17, 2015
 * Author: Thomas Herzog
 */

#include "MLCollection.h"
#include "Node.h"
#include <string>

using namespace std;
using namespace ML;

Node::Node(Object* val, Node* prev, Node* next) :
    val(val), prev(prev), next(next) {
    Register("Node", "Object");
} /* Node::Node */

Node::~Node() {
    // Nothing to do. Member handled outside this instance
} /* Node::~Node */

string Node::AsString() const {
    string asString("Node (");
    (val != nullptr) ?
        asString.append(val->AsString()) : asString.append("nullptr");
    asString.append(")");
    return asString;
} /* Node::AsString */
```

2.2.5 Set.h

Folgend ist die Spezifikation des Set Containers angeführt.

```
/*
 * Set.h
 * This is the specification of the Set container
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */

#ifndef SET_H_
#define SET_H_

#include "List.h"

/**
 * This class implements a set container which disallows duplicate values in the container.
 * It inherits from List and adds check functionality on appending methods to check if the
 * value is already managed.
 *
 * There is no need to define new iterator because would not differ from List implemented one.
 */
class Set: public List {
protected:
    /**
     * Answers the question if this container has already a node which wraps the given
     * value.
     * It prints a message to the console if value is already managed by this set.
     *
     * @param:
     *     obj: the value to be checked if already managed by the set
     * @return:
     *     true if already managed, false otherwise.
     */
    virtual bool IsAlreadyManaged(ML::Object* obj) const;

public:
```

```

// #####
// Constructor and destructor
// #####
/**
 * This constructor does nothing since List provides all necessary functionality.
 */
Set();

/**
 * This destructor does nothing since this set has no dynamic members.
 */
virtual ~Set();

// #####
// overwritten for Set behavior
// #####
/**
 * Overwritten to avoid duplicates.
 * @see List::Add(Object* object)
 */
virtual void Add(ML::Object* object);

/**
 * Overwritten to avoid duplicates.
 * @see List::Append(Object* object)
 */
virtual void Append(ML::Object* object);

/**
 * Overwritten to avoid duplicates.
 * @see List::Prepend(Object* object)
 */
virtual void Prepend(ML::Object* object);

// #####
// utils
// #####
/**
 * Builds a intersection between this set and the given one.
 * This set will be modified and will become the intersected set
 *
 * @param:
 *     set: the set to intersect with
 */
virtual void Intersect(Set* set);

/**
 * Builds a union between this set and the given one.
 * This set will represent the united set.
 *
 * @param:
 *     set: the set to unite with this set
 */
virtual void Union(Set* set);

/**
 * Builds a complement between this set and the given one.
 * This set will represent the complemented set.
 *
 * @param:
 *     set: the set to build the complemented with this set
 */
virtual void Complement(Set* set);
};

#endif /* SET_H_ */

```

2.2.6 Set.cpp

Folgend ist die Implementierung der Spezifikation Set.h angeführt.

```

/*
 * Set.cpp
 * This is the implementation of the Set container specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#include "Set.h"

using namespace std;
using namespace ML;

Set::Set() :
    List() {
    Register("Set", "List");
    // Nothing to do. List initializes backed container
} /* Set::Set */

Set::~Set() {
    // Nothing to do
} /* Set::~Set */

bool Set::IsAlreadyManaged(Object* object) const {
    Node* node = Find(object);
    if (node != nullptr) {
        cout << "Object already managed by this set !!!" << endl << flush;
    } /* if */
    return node != nullptr;
} /* Set::IsAlreadyManaged */

void Set::Add(ML::Object* object) {
    /* avoid duplicates */
    if (!IsAlreadyManaged(object)) {
        List::Add(object);
    } /* if */
} /* Set::Add */

void Set::Append(ML::Object* object) {
    /* avoid duplicates */
    if (!IsAlreadyManaged(object)) {
        List::Append(object);
    } /* if */
} /* Set::Append */

void Set::Prepend(ML::Object* object) {
    /* avoid duplicates */
    if (!IsAlreadyManaged(object)) {
        List::Prepend(object);
    } /* if */
} /* Set::Prepend */

void Set::Intersect(Set* set) {
    /* null set not allowed will not change anything */
    if (set == nullptr) {
        cout << "Given set is not allowed to be null !!!" << endl << flush;
    }
    /* if source is empty this set cannot contain any element */
    else if (set->Size() == 0) {
        Clear();
    }
    /* find out what to nodes are supposed to be removed */
    else {
        Iterator* it = NewIterator();
        Object* obj = it->Next();
        while (obj != nullptr) {
            if (set->Find(obj) == nullptr) {
                Remove(obj);
            } /* if */
            obj = it->Next();
        } /* while */

        delete it;
    }
}

```

```

    } /* if */
} /* Set::Intersect */

void Set::Union(Set* set) {
    /* null set not allowed will not change anything */
    if (set == nullptr) {
        cout << "Given set is not allowed to be null !!!" << endl << flush;
    }
    /* if source wempty nothign to do */
    else if (set->Size() > 0) {
        Iterator* it = set->NewIterator();
        Object* obj = it->Next();
        while (obj != nullptr) {
            if (Find(obj) == nullptr) {
                Append(obj);
            } /* if */
            obj = it->Next();
        } /* while */

        delete it;
    } /* if */
} /* Set::Union */

void Set::Complement(Set* set) {
    /* null set not allowed will not change anything */
    if (set == nullptr) {
        cout << "Given set is not allowed to be null !!!" << endl << flush;
    }
    /* if source is empt nothing to do */
    else if (set->Size() > 0) {
        Iterator* it = set->NewIterator();
        Object* obj = it->Next();
        while (obj != nullptr) {
            if (Find(obj) != nullptr) {
                Remove(obj);
            } /* if */
            obj = it->Next();
        } /* while */

        delete it;
    } /* if */
} /* Set::Complement */

```

2.2.7 SetTest.h

Folgend ist die Spezifikation der Test für den Set Container angeführt.

```

/*
 * SetTest.h
 * This is the Set Test specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */

#ifndef SETTEST_H
#define SETTEST_H

#include "cute.h"
#include "../Set.h"

cute::suite makeSetTestSuite();

// #####
// Add, Append, Prepend tests
// #####
void test_set_add_mulptile_values();

void test_set_append_mulptile_values();

void test_set_prepend_mulptile_values();

// #####
// Remove tests
// #####
void test_set_remove_not_found();

void test_set_remove_empty();

void test_set_remove();

// #####
// Intersect tests
// #####
void test_set_intersect_null_source();

void test_set_intersect_empty_source();

void test_set_intersect_empty_result();

void test_set_intersect();

// #####
// union tests
// #####
void test_set_union_null_source();

void test_set_union_empty_source();

void test_set_union_duplicates();

void test_set_union();

// #####
// complement tests
// #####
void test_set_complement_null_source();

void test_set_complement_empty_source();

void test_set_complement_duplicates();

void test_set_complement();

#endif /* SETTEST_H */

```

2.2.8 SetTest.cpp

Folgend ist die Implementierung der Spezifikation SetTest.h angeführt.

```

/*
 * SetTest.cpp
 * This is the implementation of the Set Test specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#include "SetTest.h"
#include "MLString.h"

using namespace cute;
using namespace ML;
using namespace std;

suite makeSetTestSuite() {
    suite setTestSuite;
    setTestSuite.push_back(CUTE(test_set_add_mulpile_values));
    setTestSuite.push_back(CUTE(test_set_append_mulpile_values));
    setTestSuite.push_back(CUTE(test_set_prepend_mulpile_values));

    setTestSuite.push_back(CUTE(test_set_remove_not_found));
    setTestSuite.push_back(CUTE(test_set_remove_empty));
    setTestSuite.push_back(CUTE(test_set_remove));

    setTestSuite.push_back(CUTE(test_set_intersect_null_source));
    setTestSuite.push_back(CUTE(test_set_intersect_empty_source));
    setTestSuite.push_back(CUTE(test_set_intersect_empty_result));
    setTestSuite.push_back(CUTE(test_set_intersect));

    setTestSuite.push_back(CUTE(test_set_union_null_source));
    setTestSuite.push_back(CUTE(test_set_union_empty_source));
    setTestSuite.push_back(CUTE(test_set_union_duplicates));
    setTestSuite.push_back(CUTE(test_set_union));

    setTestSuite.push_back(CUTE(test_set_complement_null_source));
    setTestSuite.push_back(CUTE(test_set_complement_empty_source));
    setTestSuite.push_back(CUTE(test_set_complement_duplicates));
    setTestSuite.push_back(CUTE(test_set_complement));

    return setTestSuite;
}

// #####
// Add, Append, Prepend tests
// #####
void test_set_add_mulpile_values() {
    Set* set = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    set->Add(val1);
    set->Add(val2);
    set->Add(val3);
    set->Add(val4);
    /* Add duplicates */
    set->Add(val1);
    set->Add(val2);

    cout << *set << endl << flush;

    ASSERT_EQUAL(4, set->Size());

    delete set;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_set_append_mulpile_values() {

```

```

Set* set = new Set();
String* val1 = new String("value 1");
String* val2 = new String("value 2");
String* val3 = new String("value 3");
String* val4 = new String("value 4");

set->Append(val1);
set->Append(val2);
set->Append(val3);
set->Append(val4);
/* Append duplicates */
set->Append(val1);
set->Append(val2);

cout << *set << endl << flush;

ASSERT_EQUAL(4, set->Size());

delete set;
delete val1;
delete val2;
delete val3;
delete val4;
}

void test_set_prepend_mulpile_values() {
Set* set = new Set();
String* val1 = new String("value 1");
String* val2 = new String("value 2");
String* val3 = new String("value 3");
String* val4 = new String("value 4");

set->Prepend(val1);
set->Prepend(val2);
set->Prepend(val3);
set->Prepend(val4);
/* Prepend duplicates */
set->Prepend(val1);
set->Prepend(val2);

cout << *set << endl << flush;

ASSERT_EQUAL(4, set->Size());

delete set;
delete val1;
delete val2;
delete val3;
delete val4;
}

// #####
// Remove tests
// #####
void test_set_remove_not_found() {
Set* set = new Set();
String* val1 = new String("value 1");
String* val2 = new String("value 2");
String* val3 = new String("value 3");

set->Add(val1);
set->Add(val2);

cout << "Before remove:" << endl << *set << endl << endl << flush;

set->Remove(val3);

cout << "After remove:" << endl << *set << endl << flush;

ASSERT_EQUAL(2, set->Size());

delete set;
delete val1;
delete val2;
delete val3;
}

```



```

void test_set_remove_empty() {
    Set* set = new Set();
    String* val3 = new String("value 3");

    cout << "Before remove:" << endl << *set << endl << endl << flush;

    set->Remove(val3);

    cout << "After remove:" << endl << *set << endl << flush;

    ASSERT_EQUAL(0, set->Size());

    delete set;
    delete val3;
}

void test_set_remove() {
    Set* set = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    set->Add(val1);
    set->Add(val2);

    cout << "Before remove:" << endl << *set << endl << endl << flush;

    set->Remove(val2);

    cout << "After remove:" << endl << *set << endl << flush;

    ASSERT_EQUAL(1, set->Size());

    delete set;
    delete val1;
    delete val2;
}

// #####
// Intersect
// #####
void test_set_intersect_null_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    target->Intersect(nullptr);

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete val1;
    delete val2;
}

void test_set_intersect_empty_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();

    target->Intersect(source);

    ASSERT_EQUAL(0, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
}

```

```

void test_set_intersect_empty_result() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");
    source->Add(val3);
    source->Add(val4);

    cout << "Target:" << endl << *target << endl << endl << flush;
    cout << "Source:" << endl << *source << endl << endl << flush;

    target->Intersect(source);

    cout << "After Intersect Target:" << endl << *target << endl << endl
        << flush;

    ASSERT_EQUAL(0, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_set_intersect() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 1");
    String* val4 = new String("value 4");
    source->Add(val3);
    source->Add(val4);

    cout << "Target:" << endl << *target << endl << endl << flush;
    cout << "Source:" << endl << *source << endl << endl << flush;

    target->Intersect(source);

    cout << "After intersect Target:" << endl << *target << endl << endl
        << flush;

    ASSERT_EQUAL(1, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

// #####
// union tests
// #####
void test_set_union_null_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    cout << "Target:" << endl << *target << endl << endl << flush;

    target->Union(nullptr);
}

```

```

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete val1;
    delete val2;
}

void test_set_union_empty_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();

    cout << "Target:" << endl << *target << endl << endl << flush;
    cout << "Source:" << endl << *source << endl << endl << flush;

    target->Union(source);

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
}

void test_set_union_duplicates() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 1");
    String* val4 = new String("value 2");
    source->Add(val3);
    source->Add(val4);

    cout << "Target:" << endl << *target << endl << endl << flush;
    cout << "Source:" << endl << *source << endl << endl << flush;

    target->Union(source);

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_set_union() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");
    source->Add(val3);
    source->Add(val4);

```

```

cout << "Target:" << endl << *target << endl << endl << flush;
cout << "Source:" << endl << *source << endl << endl << flush;

target->Union(source);

cout << "After intersect Target:" << endl << *target << endl << endl
    << flush;

ASSERT_EQUAL(4, target->Size());

delete target;
delete source;
delete val1;
delete val2;
delete val3;
delete val4;
}

// #####
// complement tests
// #####
void test_set_complement_null_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    cout << "Target:" << endl << *target << endl << endl << flush;

    target->Complement(nullptr);

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete val1;
    delete val2;
}

void test_set_complement_empty_source() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();

    cout << "Target:" << endl << *target << endl << endl << flush;

    target->Complement(source);

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
}

void test_set_complement_duplicates() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 1");
    String* val4 = new String("value 2");
    source->Add(val3);
    source->Add(val4);
}

```

```

cout << "Target:" << endl << *target << endl << endl << flush;
cout << "Source:" << endl << *source << endl << endl << flush;

target->Complement(source);

cout << "After union Target:" << endl << *target << endl << endl << flush;

ASSERT_EQUAL(0, target->Size());

delete target;
delete source;
delete val1;
delete val2;
delete val3;
delete val4;
}

void test_set_complement() {
    Set* target = new Set();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    target->Add(val1);
    target->Add(val2);

    Set* source = new Set();
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");
    source->Add(val3);
    source->Add(val4);

    cout << "Target:" << endl << *target << endl << endl << flush;
    cout << "Source:" << endl << *source << endl << endl << flush;

    target->Complement(source);

    cout << "After union Target:" << endl << *target << endl << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

```

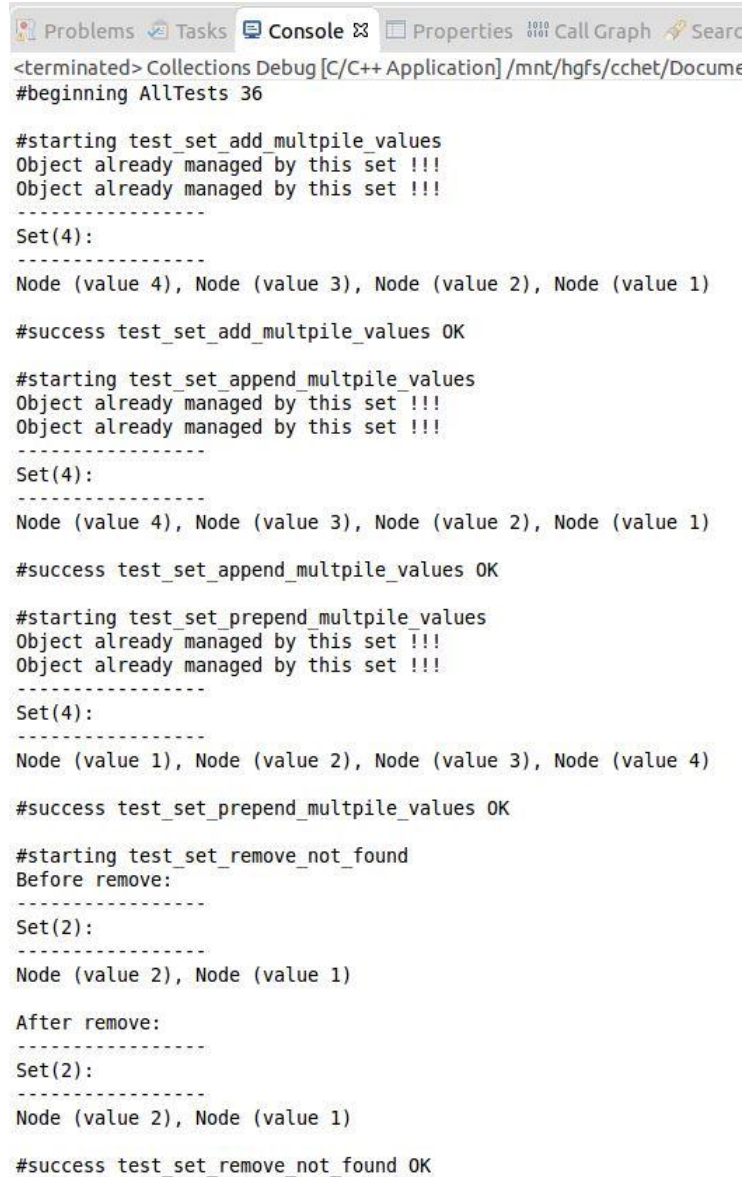
2.3 Tests

Folgend sind die Tests für die Set Implementierung angeführt.

Es wird hierbei davon ausgegangen das die List Implementierung korrekt funktioniert.

Sie wird in diesen Tests sowieso implizit getestet, bis auf die Möglichkeit Duplikate einzufügen.

Da alle Tests auf einmal durchlaufen erfolgt die Ausgabe der Meta-Informationen am Ende der Bag Tests.



```
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Docume
#beginning AllTests 36

#starting test_set_add_mulpile_values
Object already managed by this set !!!
Object already managed by this set !!!
-----
Set(4):
-----
Node (value 4), Node (value 3), Node (value 2), Node (value 1)

#success test_set_add_mulpile_values OK

#starting test_set_append_mulpile_values
Object already managed by this set !!!
Object already managed by this set !!!
-----
Set(4):
-----
Node (value 4), Node (value 3), Node (value 2), Node (value 1)

#success test_set_append_mulpile_values OK

#starting test_set_prepend_mulpile_values
Object already managed by this set !!!
Object already managed by this set !!!
-----
Set(4):
-----
Node (value 1), Node (value 2), Node (value 3), Node (value 4)

#success test_set_prepend_mulpile_values OK

#starting test_set_remove_not_found
Before remove:
-----
Set(2):
-----
Node (value 2), Node (value 1)

After remove:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_remove_not_found OK
```



The screenshot shows a Visual Studio console window with the following output:

```
<terminated> Collections Debug [C/C++ Application] /mn
#starting test_set_remove_empty
Before remove:
-----
Set(0):
-----

After remove:
-----
Set(0):
-----

#success test_set_remove_empty OK

#starting test_set_remove
Before remove:
-----
Set(2):
-----
Node (value 2), Node (value 1)

After remove:
-----
Set(1):
-----
Node (value 1)

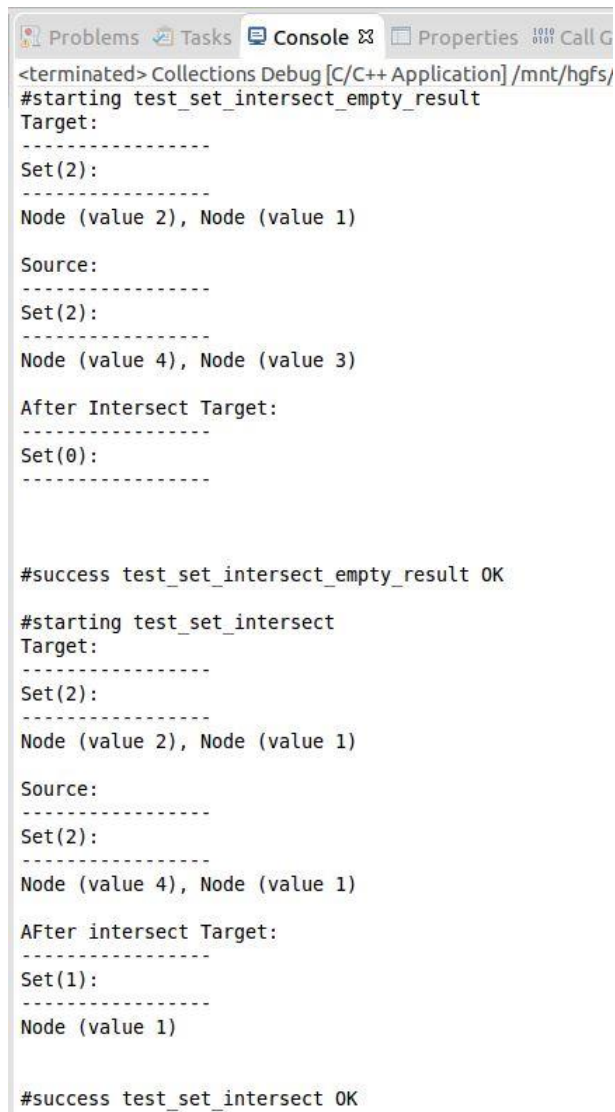
#success test_set_remove OK

#starting test_set_intersect_null_source
Given set is not allowed to be null !!!

#success test_set_intersect_null_source OK

#starting test_set_intersect_empty_source

#success test_set_intersect_empty_source OK
```



```
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/
#starting test_set_intersect_empty_result
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 4), Node (value 3)

After Intersect Target:
-----
Set(0):
-----

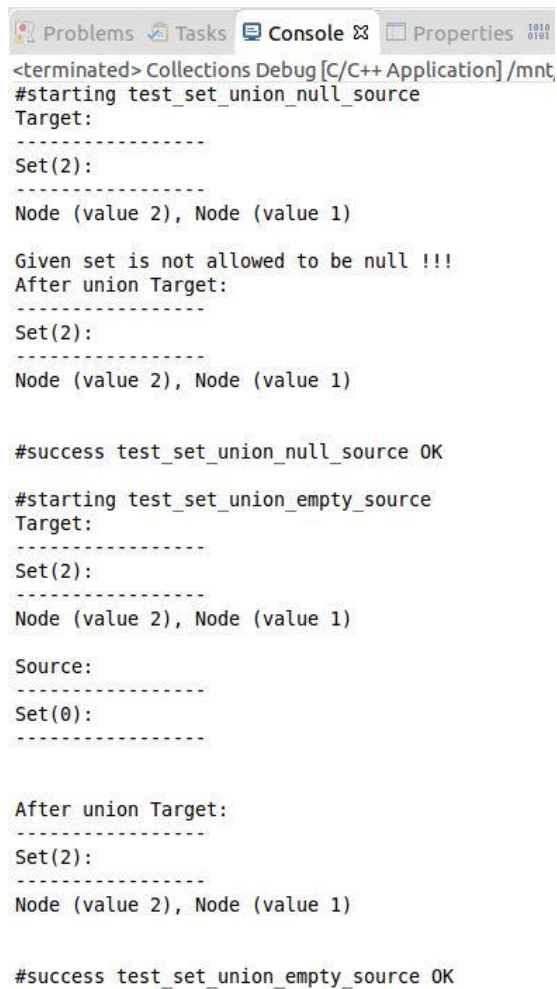
#success test_set_intersect_empty_result OK

#starting test_set_intersect
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 4), Node (value 1)

After intersect Target:
-----
Set(1):
-----
Node (value 1)

#success test_set_intersect OK
```

The screenshot shows a console window with tabs for Problems, Tasks, Console, and Properties. The Console tab is active, displaying the output of a C++ application. The output includes two test cases: 'test_set_union_null_source' and 'test_set_union_empty_source'. Both tests pass, indicated by 'OK' at the end of each test block. The output also shows the state of a set and its nodes before and after union operations.

```
<terminated> Collections Debug [C/C++ Application] /mnt
#starting test_set_union_null_source
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Given set is not allowed to be null !!!
After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

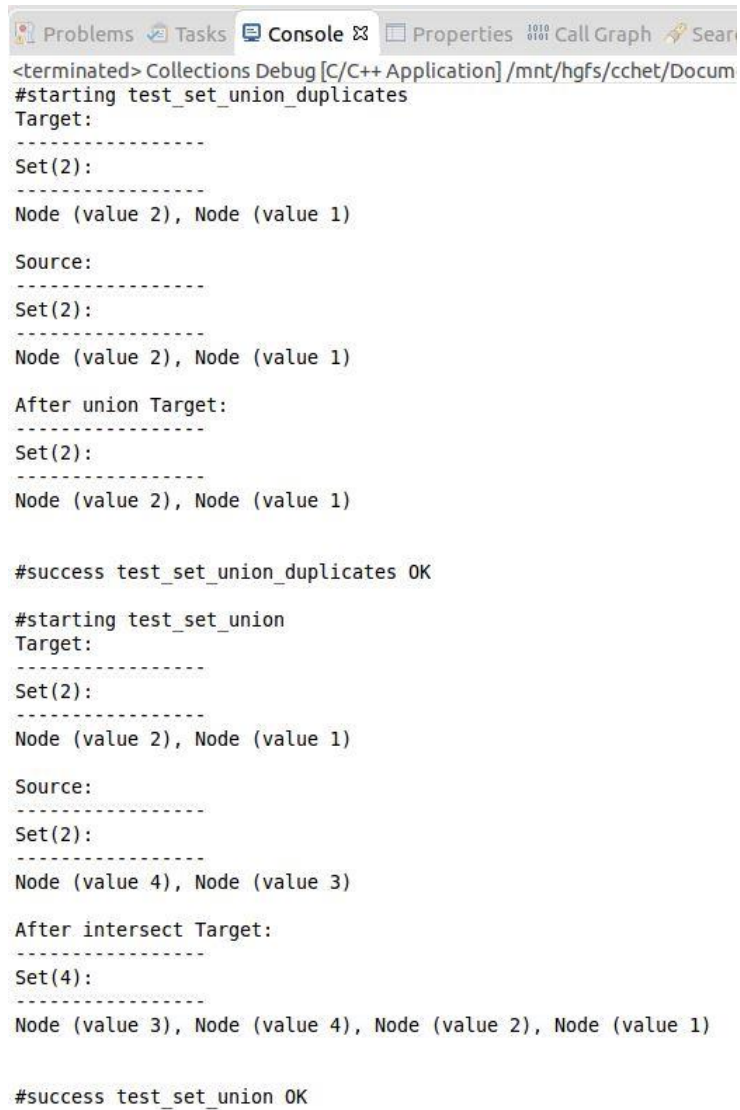
#success test_set_union_null_source OK

#starting test_set_union_empty_source
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(0):
-----

After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_union_empty_source OK
```



```
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Docum
#starting test_set_union_duplicates
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 2), Node (value 1)

After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_union_duplicates OK

#starting test_set_union
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 4), Node (value 3)

After intersect Target:
-----
Set(4):
-----
Node (value 3), Node (value 4), Node (value 2), Node (value 1)

#success test_set_union OK
```



The screenshot shows a C++ IDE with a console window. The console output displays the results of two test cases: `test_set_complement_null_source` and `test_set_complement_empty_source`. Both tests pass, indicated by the `OK` status. The output for each test includes the initial state of a set, the result of a union operation, and a confirmation message.

```
<terminated> Collections Debug [C/C++ Application] /mnt/
#starting test_set_complement_null_source
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

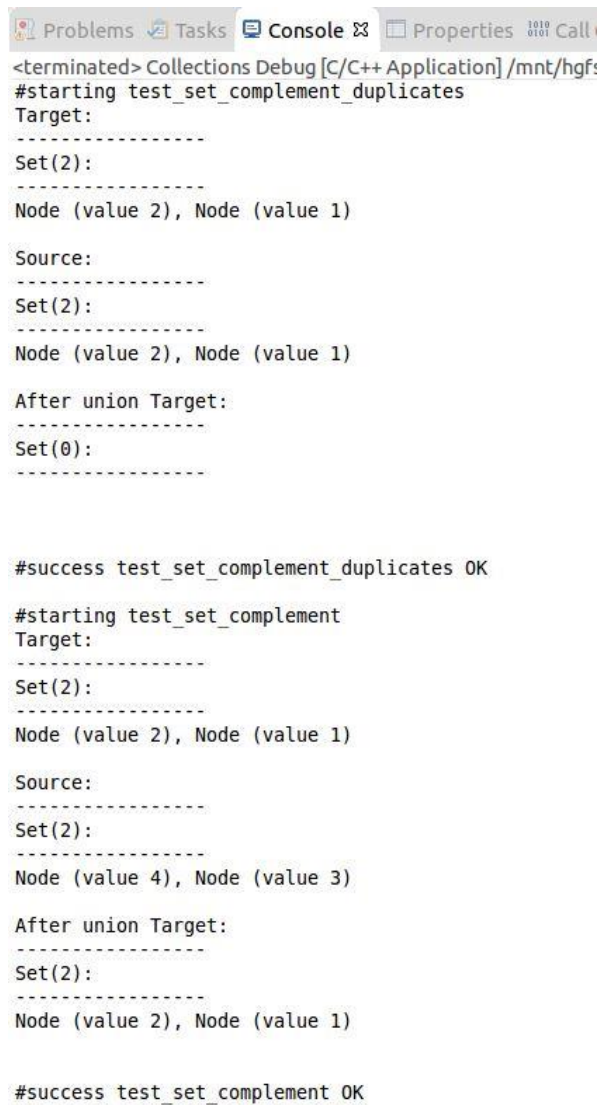
Given set is not allowed to be null !!!
After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_complement_null_source OK

#starting test_set_complement_empty_source
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_complement_empty_source OK
```



```

<terminated> Collections Debug [C/C++ Application] /mnt/hgfs:
#starting test_set_complement_duplicates
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 2), Node (value 1)

After union Target:
-----
Set(0):
-----

#success test_set_complement_duplicates OK

#starting test_set_complement
Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

Source:
-----
Set(2):
-----
Node (value 4), Node (value 3)

After union Target:
-----
Set(2):
-----
Node (value 2), Node (value 1)

#success test_set_complement OK

```

3 Objektbehälter (Bag)

Folgend ist die Dokumentation der zweiten Aufgabenstellung angeführt.

3.1 Lösungsidee

Laut Aufgabenstellung soll dieser Container von Set ableiten und dieselben Funktionalitäten zur Verfügung stellen, was an sich nicht in Ordnung ist, da Mengenoperationen auf Mengen angewendet werden sollten und der Bag Container nun mahl keine Menge darstellt, da er Duplikate erlaubt. Daher müssen die Mengenoperationen erneut implementiert und deren Verhalten spezifiziert werden. Dies wird später genauer erläutert.

Um Speicherschonend arbeiten zu können sollen die Duplikate nicht gespeichert sondern lediglich die Anzahl der Werte, die im Container verwaltet werden, gespeichert werden. Dies stellt kein Problem dar, da die Duplikate exakt dem gespeicherten Wert entsprechen und sich von diesen nicht unterscheiden. Hierbei verlässt man sich auf die Methode `IsEqualTo(...)`, die `true` zurückliefert wenn zwei Objekt gleich sind und `false` wenn nicht.

Daher soll die Klasse `BagNode` eingeführt werden, die von `Node` ableitet und sich die Anzahl der Werte im Container merken soll.

Der Bag Container soll aber trotzdem die Anzahl aller gespeicherten Werte halten obwohl diese nicht die tatsächliche Anzahl der verwalteten Knoten widerspiegelt. Da aber mittels Iterator über die Elemente iteriert wird und dieser unabhängig von der aktuellen Anzahl und der gehaltenen Größe ist, stellt dies kein Problem dar. Der Iterator braucht die gehaltene `Size` nicht.

Bei einer Iteration über die Elemente soll nur über die aktuell verwalteten Knoten iteriert werden und der Aufrufer ist verantwortlich sich um die Duplikate, welche über die gehaltene Anzahl in der Klasse `BagNode` definiert ist, zu kümmern. Damit ist gemeint der Aufrufer muss sich im Klaren sein, dass die Duplikate nur über die Anzahl definiert sind und nicht im Container als Knoten vorhanden sind.

3.1.1 Spezifikation der Mengenoperationen

Im Folgenden wird die aktuelle Instanz über die die Operationen durchgeführt werden als Target und die übergebene Bag Container Instanz als Source bezeichnet.

Um die Performanz zu steigern sollen die Duplikate mittels Arithmetik hinzugefügt oder entfernt werden. Damit ist gemeint sollten Duplikate erkannt werden sollen diese über Arithmetik der Anzahl hinzugefügt oder entfernt werden. Nur der Knoten, der tatsächlich im Container vorhanden ist oder hinzugefügt werden muss, soll wie gehabt in den Container hinzugefügt oder gelöscht werden.

Die Remove und Append Methode würden zwar funktionieren, jedoch wären zu viele Iterationen über die backing List erforderlich, was hierbei nicht notwendig ist.

Das folgend spezifizierte Verhalten der Mengenoperationen betrachtet die Duplikate als wären Sie gültige Elemente einer Menge und ignoriert das sie eigentlich Duplikate sind.

Schnittmenge:

1. Knoten im Target, die mehr Duplikate definieren als die Knoten im Source, sollen die Anzahl der Duplikate der Knoten des Source widerspiegeln.
2. Knoten im Target, die weniger Duplikate definieren als die Knoten im Source, sollen so verbleiben und nicht geändert werden.
3. Knoten die im Target vorhanden sind aber nicht im Source sollen vollständig gelöscht werden.

Vereinigung:

1. Knoten die im Source vorhanden sind aber nicht im Target sollen mit Ihren Duplikaten in den Target Container übernommen werden.
2. Knoten die Im Target vorhanden sind aber weniger Duplikate definieren, sollen die Anzahl der Duplikate des Knoten im Source widerspiegeln.
3. Knoten die im Target vorhanden sind und mehr Duplikate definieren als die Knoten im Source sollen so verbleiben wie sie sind.

Komplement:

1. Knoten die im Target und Source vorhanden sind, sollen vollständig gelöscht werden wenn
 - a. der Knoten im Target weniger Duplikate definiert als die Knoten im Source
 - b. ansonsten sollen die Knoten des Target die
Summe: $\text{targetNode.count} - \text{sourceNode.count}$ als Duplikate definieren.
2. Knoten die im Target vorhanden sind und weniger Duplikate definieren als die Knoten im Source, sollen vollständig entfernt werden.
3. Knoten die nur im Target vorhanden sind sollen unverändert bleiben.

3.2 Implementierung

Folgend sind die Implementierung der zweiten Aufgabenstellung angeführt.

3.2.1 BagNode.h

Folgend ist die Spezifikation Gab Knoten angeführt.

```

/*
 * BagNode.h
 * This is the bag container BagNode specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */

#ifndef BAGNODE_H_
#define BAGNODE_H_

#include "List.h"
#include <string>

/**
 * This class can be used in bag implementation which holds information about the count of the
 * duplicates.
 * Therefore that we talk about duplicates we do not need to hold the references or copy the
 * duplicates, the duplicate count provides enough information,
 * since a bagNode instance will provide all necessary information about the node and its
 * duplicates.
 */
class BagNode: public Node {
public:
    /**
     * The count of the duplicate nodes.
     */
    int count;

    /**
     * Constructor which only sets the count to 1.
     * The rest is done by the parent class
     */
    explicit BagNode(ML::Object* val = nullptr, Node* prev = nullptr, Node* next =
        nullptr);

    /**
     * Destructor which does nothing because no dynamic members.
     */
    ~BagNode();

    /**
     * Returns the string representation of this instance.
     *
     * @return:
     *         the string representation of this node
     */
    virtual std::string AsString() const;
};

#endif /* BAGNODE_H_ */

```

3.2.2 BagNode.cpp

Folgend ist die Implementierung der Spezifikation BagNode.h angeführt.

```

/*
 * BagNode.cpp
 * This is the implementation of the bag container BagNode specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#include "BagNode.h"
#include <sstream>

using namespace std;
using namespace ML;

BagNode::BagNode(ML::Object* val, Node* prev, Node* next) :
    Node(val, prev, next), count(1) {
    Register("BagNode", "Node");
} /* BagNode::BagNode */

BagNode::~BagNode() {
    // nothing to do
} /* BagNode::~BagNode */

std::string BagNode::AsString() const {
    string result("BagNode(");
    /* seems std::to_string not supported by this compiler */
    stringstream ss;
    ss << count;
    (val != nullptr) ?
        result.append(val->AsString()) : result.append("nullptr");
    result.append(", ").append(ss.str()).append(")");
    return result;
} /* BagNode::AsString */

```


3.2.3 Bag.h

Folgend ist die Spezifikation des Bag Container angeführt.

```

/*
 * Bag.h
 * This is the Bag container specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */

#ifndef BAG_H
#define BAG_H

#include "Set.h"
#include "BagNode.h"

/**
 * This class realizes a bag container and inherits from the Set class which provides the
 * proper implementation.
 * Since this container will not contain duplicates nodes (duplicates count on BagNode only),
 * we can inherit from Set
 * and not from List.
 * There is no need to create own nodes for the duplicates since the duplicates will not
 * provide more information
 * as the unique instance would do.
 */
class Bag: public Set {
protected:
    /**
     * Overwritten for type safety.
     * @see: Node* Set::Find(Object* obj)
     */
    BagNode* Find(ML::Object* object) const;

public:
    // #####
    // Constructor and destructor
    // #####
    /**
     * Constructor which does nothing because handled by parent class
     */
    Bag();

    /**
     * Destructor which does nothing because no dynamic members.
     */
    virtual ~Bag();

    // #####
    // overwritten for Bag behavior
    // #####
    /**
     * Overwritten to allow duplicates and handle them properly.
     * @see Set::Add(Object* object)
     */
    virtual void Add(ML::Object* object);

    /**
     * Overwritten to allow duplicates and handle them properly.
     * @see Set::Append(Object* object)
     */
    virtual void Append(ML::Object* object);

    /**
     * Overwritten to allow duplicates and handle them properly.
     * @see Set::Prepend(Object* object)
     */
    virtual void Prepend(ML::Object* object);

    /**
     * Deletes one of the duplicates if more than one item is present otherwise parent
     class handles deletion.
     *
     * @param:

```

```

        *      object: the object to be deleted
        */
virtual ML::Object* Remove(ML::Object* object);

// #####
// overwritten for type safety and bag behavior .utils
// #####
/**
 * Special handling for Bag container, since a set is not allowed to contain
duplicates but a bag does
 * we need to handle this intersection differently.
 *
 * 1. If a target node does not exist in the source will be removed completely.
 * 2. If a target node has less duplicates defined than the target node will remain as
it is.
 * 3. If a target node has more duplicates defined as the source node than the target
node will define the source node defined duplicate count.
 */
virtual void Intersect(Bag* bag);

/**
 * Special handling for Bag container, since since a set is not allowed to contain
duplicates but a bag does
 * we need to handle this intersection differently.
 *
 * 1. If a node exists in the source but not the target then this node will be
appended to this container with the
 *      current set duplicate count of the source node
 * 2. If a target node has less duplicates as a source node increases the duplicate
counter to face the source node duplicate count.
 * 3. If a target node has more duplicates defined as the source node will not be
modified.
 */
virtual void Union(Bag* bag);

/**
 * Special handling for Bag container, since since a set is not allowed to contain
duplicates but a bag does
 * we need to handle this intersection differently.
 *
 * 1. If a node exists in the source and target and the target node has more
duplicates defined,
 *      then the target node will define the sum: targetNode.count - sourceNode.count;
 * 2. If a node exists in the source and target node and the target node has less
duplicates defined,
 *      then the node will be removed completely
 * 3. If a target node does not exist in the source then this node remains as it is
 */
virtual void Complement(Bag* bag);

// #####
// operator
// #####
/**
 * The operator which prints this bag instance.
 * The already in List implemented Method Print will be reused since there is no
difference in the printed result.
 * The nodes will provide their own AsString method and therefore the nodes will be
printed properly.
 */
friend std::ostream & operator<<(std::ostream & os, const Bag & bag);

};

#endif /* BAG_H_ */

```

3.2.4 Bag.cpp

Folgend ist die Implementierung der Spezifikation Bag.h angeführt.

```

/*
 * Bag.cpp
 * This is the implementation of the bag container specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#include "Bag.h"

using namespace std;
using namespace ML;

Bag::Bag() :
    Set() {
    Register("Bag", "Set");
} /* Bag::Bag */

Bag::~Bag() {
    // Nothing to do
} /* Bag::~Bag */

BagNode* Bag::Find(Object* object) const {
    /* Save for brutal cast because only BagNode instances are allowed */
    return (BagNode*) Set::Find(object);
} /* Bag::Find */

void Bag::Add(Object* object) {
    Append(object);
} /* Bag::Add */

void Bag::Append(Object* object) {
    BagNode* node = Find(object);
    /* no duplicates, normal append */
    if (node == nullptr) {
        BagNode* newNode = new BagNode(object, anchor->prev,
            anchor->prev->next);
        anchor->prev = newNode;
        newNode->prev->next = newNode;
    }
    /* else increase count of duplicates */
    else {
        node->count++;
    } /* if */
    size++;
} /* Bag::Append */

void Bag::Prepend(Object* object) {
    BagNode* node = Find(object);
    /* no duplicates, normal prepend */
    if (node == nullptr) {
        BagNode* newNode = new BagNode(object, anchor->next->prev,
            anchor->next);
        anchor->next = newNode;
        newNode->next->prev = newNode;
    }
    /* else increase count of duplicates */
    else {
        node->count++;
    } /* if */
    size++;
} /* Bag::Prepend */

Object* Bag::Remove(Object* object) {
    BagNode* node = Find(object);
    /* if node found and has duplicates */
    if ((node != nullptr) && (node->count > 1)) {
        node->count--;
        size--;
        return object;
    }
    /* else delegate to parent class */
    else {

```

```

        return Set::Remove(object);
    } /* if */
} /* Bag::Remove */

void Bag::Intersect(Bag* bag) {
    if (bag == nullptr) {
        cout << "Given set is not allowed to be null !!!" << endl << flush;
    } else if (bag->Size() == 0) {
        Clear();
    } else {
        Iterator* it = NewIterator();
        Object* obj = it->Next();
        BagNode* bagNode = nullptr;
        BagNode* thisNode = nullptr;
        while (obj != nullptr) {
            thisNode = Find(obj);
            /* node not present in source bag */
            if ((bagNode = bag->Find(obj)) == nullptr) {
                /* remove all nodes with duplicates */
                size -= (thisNode->count - 1);
                Remove(obj);
            }
            /* append as much as common */
            else if (thisNode->count > bagNode->count) {
                /* remove too much duplicates */
                int diff = (thisNode->count - bagNode->count);
                thisNode->count = (thisNode->count - diff);
                size -= diff;
            } /* if */
            obj = it->Next();
        } /* while */

        delete it;
    } /* if */
} /* Bag::Intersect */

void Bag::Union(Bag* bag) {
    if (bag == nullptr) {
        cout << "Given Bag is not allowed to be null !!!" << endl << flush;
    } else if (bag->Size() > 0) {
        Iterator* it = bag->NewIterator();
        Object* obj = it->Next();
        BagNode* bagNode = nullptr;
        BagNode* thisNode = nullptr;
        while (obj != nullptr) {
            bagNode = bag->Find(obj);
            /* node found in this bag */
            if ((thisNode = Find(obj)) == nullptr) {
                Append(obj);
                Find(obj)->count += (bagNode->count - 1);
                size += (bagNode->count - 1);
                /* for */
            }
            else if (thisNode->count < bagNode->count) {
                int diff = (bagNode->count - thisNode->count);
                size += diff;
                thisNode->count += diff;
            }
            /* if */
            obj = it->Next();
        } /* while */

        delete it;
    } /* if */
} /* Bag::Union */

void Bag::Complement(Bag* bag) {
    if (bag == nullptr) {
        cout << "Given set is not allowed to be null !!!" << endl << flush;
    } else if (bag->Size() > 0) {
        Iterator* it = bag->NewIterator();
        Object* obj = it->Next();
        BagNode* thisNode = nullptr;
        BagNode* bagNode = nullptr;
        while (obj != nullptr) {
            if ((thisNode = Find(obj)) != nullptr) {

```

```

        bagNode = bag->Find(obj);
        /* Only remove too much duplicates */
        if (thisNode->count > bagNode->count) {
            thisNode->count = bagNode->count;
            size -= bagNode->count;
        }
        /* if source has more than this bag remove all */
        else if (bagNode->count >= thisNode->count) {
            size -= (thisNode->count - 1);
            thisNode->count = 1;
            Remove(obj);
        } /* if */
    }
    obj = it->Next();
} /* while */

delete it;
} /* if */
} /* Bag::Complement */

ostream& operator<<(ostream & os, const Bag & bag) {
    bag.Print(os);
    return os;
} /* operator<< */

```

3.2.5 BagTest.h

Folgend ist die Spezifikation der Test für den Bag Container angeführt.

```

/*
 * BagTest.h
 * This is the Bag Test specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#ifndef BAGTEST_H
#define BAGTEST_H

#include "cute.h"
#include "../Bag.h"

cute::suite makeBagTestSuite();
// #####
// Add, Append, Prepend tests
// #####
void test_bag_add_multiple_values();

void test_bag_append_multiple_values();

void test_bag_prepend_multiple_values();

// #####
// Remove tests
// #####
void test_bag_remove_not_found();

void test_bag_remove_empty();

void test_bag_remove();

// #####
// Intersect tests
// #####
// Intersect tests
// #####
void test_bag_intersect_null_source();

void test_bag_intersect_empty_source();

void test_bag_intersect_empty_result();

```

```

void test_bag_intersect();

// #####
// union tests
// #####
void test_bag_union_null_source();

void test_bag_union_empty_source();

void test_bag_union_nothing_todo();

void test_bag_union();

// #####
// complement tests
// #####
void test_bag_complement_null_source();

void test_bag_complement_empty_source();

void test_bag_complement_empty_result();

void test_bag_complement();

#endif /* BAGTEST_H_ */

```

3.2.6 BagTest.cpp

Folgend ist die Implementierung der Spezifikation BagTest.cpp angeführt.

```

/*
 * BagTest.cpp
 * This is the implementation of the Bag Test specification.
 *
 * Created on: Jan 18, 2015
 * Author: Thomas Herzog
 */
#include "BagTest.h"
#include "MLString.h"

using namespace cute;
using namespace ML;
using namespace std;

suite makeBagTestSuite() {
    suite setTestSuite;
    setTestSuite.push_back(CUTE(test_bag_add_mulpile_values));
    setTestSuite.push_back(CUTE(test_bag_append_mulpile_values));
    setTestSuite.push_back(CUTE(test_bag_prepend_mulpile_values));

    setTestSuite.push_back(CUTE(test_bag_remove_not_found));
    setTestSuite.push_back(CUTE(test_bag_remove_empty));
    setTestSuite.push_back(CUTE(test_bag_remove));

    setTestSuite.push_back(CUTE(test_bag_intersect_null_source));
    setTestSuite.push_back(CUTE(test_bag_intersect_empty_source));
    setTestSuite.push_back(CUTE(test_bag_intersect_empty_result));
    setTestSuite.push_back(CUTE(test_bag_intersect));

    setTestSuite.push_back(CUTE(test_bag_union_null_source));
    setTestSuite.push_back(CUTE(test_bag_union_empty_source));
    setTestSuite.push_back(CUTE(test_bag_union_nothing_todo));
    setTestSuite.push_back(CUTE(test_bag_union));

    setTestSuite.push_back(CUTE(test_bag_complement_null_source));
    setTestSuite.push_back(CUTE(test_bag_complement_empty_source));
    setTestSuite.push_back(CUTE(test_bag_complement_empty_result));
    setTestSuite.push_back(CUTE(test_bag_complement));

    return setTestSuite;
}

// #####

```

```

// Add, Append, Prepend tests
// #####
void test_bag_add_multpile_values() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    bag->Add(val1);
    bag->Add(val2);
    bag->Add(val3);
    bag->Add(val4);
    /* Add duplicates */
    bag->Add(val1);
    bag->Add(val2);

    cout << *bag << endl << flush;

    ASSERT_EQUAL(6, bag->Size());

    delete bag;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_append_multpile_values() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    bag->Append(val1);
    bag->Append(val2);
    bag->Append(val3);
    bag->Append(val4);
    /* Add duplicates */
    bag->Append(val1);
    bag->Append(val2);

    cout << *bag << endl << flush;

    ASSERT_EQUAL(6, bag->Size());

    delete bag;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_prepend_multpile_values() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    bag->Prepend(val1);
    bag->Prepend(val2);
    bag->Prepend(val3);
    bag->Prepend(val4);
    /* Add duplicates */
    bag->Prepend(val1);
    bag->Prepend(val2);

    cout << *bag << endl << flush;

    ASSERT_EQUAL(6, bag->Size());

    delete bag;
    delete val1;
    delete val2;

```

```

        delete val3;
        delete val4;
    }

// #####
// Remove tests
// #####
void test_bag_remove_not_found() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");

    bag->Prepend(val1);
    bag->Prepend(val2);

    cout << "Before Remove Target: " << endl << *bag << endl << endl << flush;
    bag->Remove(val3);
    cout << "After Remove Target: " << endl << *bag << endl << flush;

    ASSERT_EQUAL(2, bag->Size());

    delete bag;
    delete val1;
    delete val2;
    delete val3;
}

void test_bag_remove_empty() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");

    cout << "Before Remove Target: " << endl << *bag << endl << endl << flush;
    bag->Remove(val1);
    cout << "After Remove Target: " << endl << *bag << endl << flush;

    ASSERT_EQUAL(0, bag->Size());

    delete bag;
    delete val1;
}

void test_bag_remove() {
    Bag* bag = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    bag->Prepend(val1);
    bag->Prepend(val2);
    bag->Prepend(val3);
    bag->Prepend(val4);
    /* Add duplicates */
    bag->Prepend(val1);
    bag->Prepend(val2);

    cout << "Before Remove Target: " << endl << *bag << endl << endl << flush;
    bag->Remove(val1);
    bag->Remove(val1);
    bag->Remove(val2);
    bag->Remove(val2);
    bag->Remove(val3);
    cout << "After Remove Target: " << endl << *bag << endl << flush;

    ASSERT_EQUAL(1, bag->Size());

    delete bag;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

// #####
// Intersect tests

```



```
// #####
void test_bag_intersect_null_source() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    target->Prepend(val1);
    target->Prepend(val2);
    target->Prepend(val3);
    target->Prepend(val4);

    cout << "Before Intersect Target: " << endl << *target << endl << endl << flush;
    target->Intersect(nullptr);
    cout << "After Intersect Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(4, target->Size());

    delete target;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_intersect_empty_source() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");

    target->Prepend(val1);
    target->Prepend(val2);
    target->Prepend(val3);
    target->Prepend(val4);

    Bag* source = new Bag();

    cout << "Before Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "Before Intersect Target: " << endl << *target << endl << endl << flush;
    target->Intersect(source);
    cout << "After Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "After Intersect Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(0, target->Size());
    ASSERT_EQUAL(0, source->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_intersect_empty_result() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val2);

    Bag* source = new Bag();
    String* val3 = new String("value 3");
    String* val4 = new String("value 4");
    source->Prepend(val3);
    source->Prepend(val4);

    cout << "Before Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "Before Intersect Target: " << endl << *target << endl << endl << flush;
    target->Intersect(source);
    cout << "After Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "After Intersect Target: " << endl << *target << endl << flush;
}
```

```

    ASSERT_EQUAL(0, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_intersect() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");
    String* val3 = new String("value 3");

    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val2);
    target->Prepend(val2);
    target->Prepend(val2);
    target->Prepend(val3);

    Bag* source = new Bag();
    String* val4 = new String("value 1");
    String* val5 = new String("value 2");
    source->Prepend(val4);
    source->Prepend(val5);
    source->Prepend(val5);
    source->Prepend(val5);
    source->Prepend(val5);
    source->Prepend(val5);
    source->Prepend(val5);

    cout << "Before Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "Before Intersect Target: " << endl << *target << endl << endl << flush;
    target->Intersect(source);
    cout << "After Intersect Source: " << endl << *source << endl << endl << flush;
    cout << "After Intersect Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(4, target->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
    delete val5;
}

// #####
// union tests
// #####
void test_bag_union_null_source() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val2);

    cout << "Before Union Target: " << endl << *target << endl << endl << flush;
    target->Union(nullptr);
    cout << "After Union Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete val1;
    delete val2;
}

void test_bag_union_empty_source() {

```

```

    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val2);

    Bag* source = new Bag();

    cout << "Before Union Source: " << endl << *source << endl << endl << flush;
    cout << "Before Union Target: " << endl << *target << endl << endl << flush;
    target->Union(source);
    cout << "After Union Source: " << endl << *source << endl << endl << flush;
    cout << "After Union Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(2, target->Size());
    ASSERT_EQUAL(0, source->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
}

void test_bag_union_nothing_todo() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val2);
    target->Prepend(val2);

    Bag* source = new Bag();
    String* val3 = new String("value 1");
    String* val4 = new String("value 2");
    source->Prepend(val3);
    source->Prepend(val3);
    source->Prepend(val4);
    source->Prepend(val4);

    cout << "Before Union Source: " << endl << *source << endl << endl << flush;
    cout << "Before Union Target: " << endl << *target << endl << endl << flush;
    target->Union(source);
    cout << "After Union Source: " << endl << *source << endl << endl << flush;
    cout << "After Union Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(4, target->Size());
    ASSERT_EQUAL(4, source->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

void test_bag_union() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val2);
    target->Prepend(val2);

    Bag* source = new Bag();
    String* val3 = new String("value 1");
    String* val4 = new String("value 2");

```

```

String* val5 = new String("value 3");
source->Prepend(val3);
source->Prepend(val4);
source->Prepend(val4);
source->Prepend(val4);
source->Prepend(val4);
source->Prepend(val4);
source->Prepend(val5);
source->Prepend(val5);

cout << "Before Union Source: " << endl << *source << endl << endl << flush;
cout << "Before Union Target: " << endl << *target << endl << endl << flush;
target->Union(source);
cout << "After Union Source: " << endl << *source << endl << endl << flush;
cout << "After Union Target: " << endl << *target << endl << flush;

ASSERT_EQUAL(10, target->Size());
ASSERT_EQUAL(7, source->Size());

delete target;
delete source;
delete val1;
delete val2;
delete val3;
delete val4;
delete val5;
}

// #####
// complement tests
// #####
void test_bag_complement_null_source() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val2);

    cout << "Before Complement Target: " << endl << *target << endl << endl << flush;
    target->Complement(nullptr);
    cout << "After Complement Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(2, target->Size());

    delete target;
    delete val1;
    delete val2;
}

void test_bag_complement_empty_source() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    target->Prepend(val1);
    target->Prepend(val2);

    Bag* source = new Bag();

    cout << "Before Complement Source: " << endl << *source << endl << endl << flush;
    cout << "Before Complement Target: " << endl << *target << endl << endl << flush;
    target->Complement(source);
    cout << "After Complement Source: " << endl << *source << endl << endl << flush;
    cout << "After Complement Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(2, target->Size());
    ASSERT_EQUAL(0, source->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
}

void test_bag_complement_empty_result() {

```

```

Bag* target = new Bag();
String* val1 = new String("value 1");
String* val2 = new String("value 2");

target->Prepend(val1);
target->Prepend(val2);

Bag* source = new Bag();
String* val3 = new String("value 1");
String* val4 = new String("value 2");

source->Prepend(val3);
source->Prepend(val4);

cout << "Before Complement Source: " << endl << *source << endl << endl << flush;
cout << "Before Complement Target: " << endl << *target << endl << endl << flush;
target->Complement(source);
cout << "After Complement Source: " << endl << *source << endl << endl << flush;
cout << "After Complement Target: " << endl << *target << endl << flush;

ASSERT_EQUAL(0, target->Size());
ASSERT_EQUAL(2, source->Size());

delete target;
delete source;
delete val1;
delete val2;
delete val3;
delete val4;
}

void test_bag_complement() {
    Bag* target = new Bag();
    String* val1 = new String("value 1");
    String* val2 = new String("value 2");

    /* target has more than source */
    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val1);
    target->Prepend(val1);
    /* target has less than source */
    target->Prepend(val2);

    Bag* source = new Bag();
    String* val3 = new String("value 1");
    String* val4 = new String("value 2");

    source->Prepend(val3);
    source->Prepend(val3);
    source->Prepend(val3);
    source->Prepend(val4);
    source->Prepend(val4);

    cout << "Before Complement Source: " << endl << *source << endl << endl << flush;
    cout << "Before Complement Target: " << endl << *target << endl << endl << flush;
    target->Complement(source);
    cout << "After Complement Source: " << endl << *source << endl << endl << flush;
    cout << "After Complement Target: " << endl << *target << endl << flush;

    ASSERT_EQUAL(1, target->Size());
    ASSERT_EQUAL(5, source->Size());

    delete target;
    delete source;
    delete val1;
    delete val2;
    delete val3;
    delete val4;
}

```

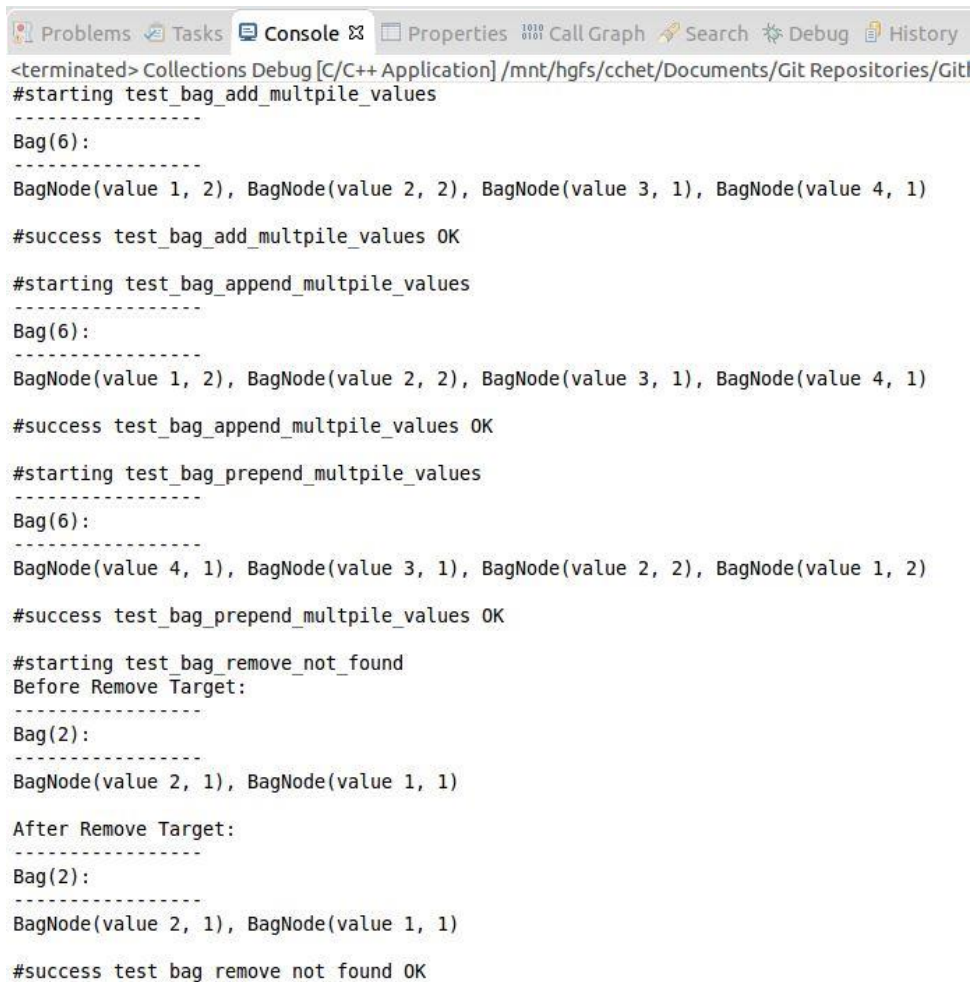
3.3 Tests

Folgend sind die Tests für die Bag Implementierung angeführt.

Es wird hierbei davon ausgegangen das die List Implementierung korrekt funktioniert.

Sie wird in diesen Tests sowieso implizit getestet, bis auf die Möglichkeit Duplikate einzufügen.

Am Ende der Tests werden die Meta-Informationen ausgegeben um zu zeigen dass alle Elemente vollständig gelöscht werden.



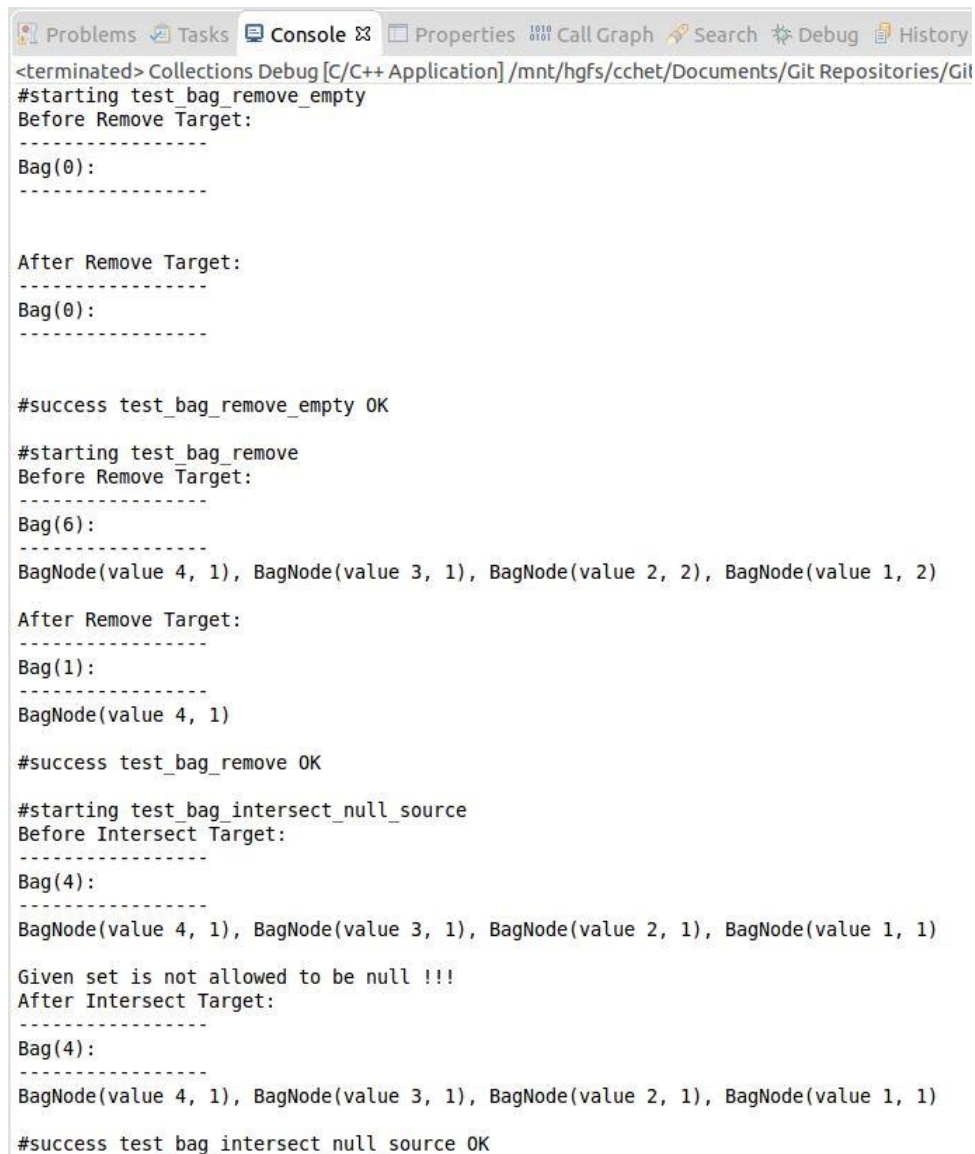
```
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Documents/Git Repositories/Gitl
#starting test_bag_add_mulpile_values
-----
Bag(6):
-----
BagNode(value 1, 2), BagNode(value 2, 2), BagNode(value 3, 1), BagNode(value 4, 1)
#success test_bag_add_mulpile_values OK

#starting test_bag_append_mulpile_values
-----
Bag(6):
-----
BagNode(value 1, 2), BagNode(value 2, 2), BagNode(value 3, 1), BagNode(value 4, 1)
#success test_bag_append_mulpile_values OK

#starting test_bag_prepend_mulpile_values
-----
Bag(6):
-----
BagNode(value 4, 1), BagNode(value 3, 1), BagNode(value 2, 2), BagNode(value 1, 2)
#success test_bag_prepend_mulpile_values OK

#starting test_bag_remove_not_found
Before Remove Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Remove Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)
#success test_bag_remove_not_found OK
```



The screenshot shows a Visual Studio Code interface with the 'Console' tab active. The console output displays the results of three test cases for a 'Bag' data structure. Each test case shows the state of the bag before and after an operation, followed by a success message.

```
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Documents/Git Repositories/Git
#starting test_bag_remove_empty
Before Remove Target:
-----
Bag(0):
-----

After Remove Target:
-----
Bag(0):
-----

#success test_bag_remove_empty OK

#starting test_bag_remove
Before Remove Target:
-----
Bag(6):
-----
BagNode(value 4, 1), BagNode(value 3, 1), BagNode(value 2, 2), BagNode(value 1, 2)

After Remove Target:
-----
Bag(1):
-----
BagNode(value 4, 1)

#success test_bag_remove OK

#starting test_bag_intersect_null_source
Before Intersect Target:
-----
Bag(4):
-----
BagNode(value 4, 1), BagNode(value 3, 1), BagNode(value 2, 1), BagNode(value 1, 1)

Given set is not allowed to be null !!!
After Intersect Target:
-----
Bag(4):
-----
BagNode(value 4, 1), BagNode(value 3, 1), BagNode(value 2, 1), BagNode(value 1, 1)

#success test_bag_intersect_null_source OK
```



```

<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Documents/Git Repositories/Githu
#starting test_bag_intersect_empty_source
Before Intersect Source:
-----
Bag(0):
-----


Before Intersect Target:
-----
Bag(4):
-----
BagNode(value 4, 1), BagNode(value 3, 1), BagNode(value 2, 1), BagNode(value 1, 1)

After Intersect Source:
-----
Bag(0):
-----

After Intersect Target:
-----
Bag(0):
-----

#success test_bag_intersect_empty_source OK

```



```

<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/
#starting test_bag_intersect_empty_result
Before Intersect Source:
-----
Bag(2):
-----
BagNode(value 4, 1), BagNode(value 3, 1)

Before Intersect Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Intersect Source:
-----
Bag(2):
-----
BagNode(value 4, 1), BagNode(value 3, 1)

After Intersect Target:
-----
Bag(0):
-----

#success test_bag_intersect_empty_result OK

```



```

Problems Tasks Console Properties Call Graph Sea
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Docun
#starting test_bag_intersect
Before Intersect Source:
-----
Bag(7):
-----
BagNode(value 2, 6), BagNode(value 1, 1)

Before Intersect Target:
-----
Bag(7):
-----
BagNode(value 3, 1), BagNode(value 2, 3), BagNode(value 1, 3)

After Intersect Source:
-----
Bag(7):
-----
BagNode(value 2, 6), BagNode(value 1, 1)

After Intersect Target:
-----
Bag(4):
-----
BagNode(value 2, 3), BagNode(value 1, 1)

#success test_bag_intersect OK

#starting test_bag_union_null_source
Before Union Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

Given Bag is not allowed to be null !!!
After Union Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

#success test_bag_union_null_source OK

```

```

Problems Tasks Console Properties
<terminated> Collections Debug [C/C++ Application] /mnt
#starting test_bag_union_empty_source
Before Union Source:
-----
Bag(0):
-----

Before Union Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Union Source:
-----
Bag(0):
-----

After Union Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

#success test_bag_union_empty_source OK

```

```

Problems Tasks Console Properties 1010 0101 Cal
<terminated> Collections Debug [C/C++ Application] /mnt/hg
#starting test_bag_union_nothing_todo
Before Union Source:
-----
Bag(4):
-----
BagNode(value 2, 2), BagNode(value 1, 2)

Before Union Target:
-----
Bag(4):
-----
BagNode(value 2, 2), BagNode(value 1, 2)

After Union Source:
-----
Bag(4):
-----
BagNode(value 2, 2), BagNode(value 1, 2)

After Union Target:
-----
Bag(4):
-----
BagNode(value 2, 2), BagNode(value 1, 2)

#success test_bag_union_nothing_todo OK

```

```

Problems Tasks Console Properties 1010 0101 Call Graph Search
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Documen
#starting test_bag_union
Before Union Source:
-----
Bag(7):
-----
BagNode(value 3, 2), BagNode(value 2, 4), BagNode(value 1, 1)

Before Union Target:
-----
Bag(6):
-----
BagNode(value 2, 2), BagNode(value 1, 4)

After Union Source:
-----
Bag(7):
-----
BagNode(value 3, 2), BagNode(value 2, 4), BagNode(value 1, 1)

After Union Target:
-----
Bag(10):
-----
BagNode(value 2, 4), BagNode(value 1, 4), BagNode(value 3, 2)

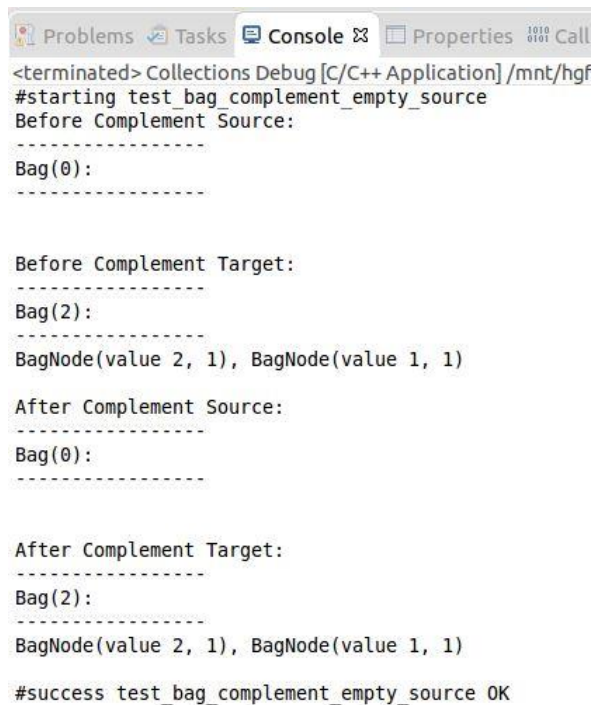
#success test_bag_union OK

#starting test_bag_complement_null_source
Before Complement Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

Given set is not allowed to be null !!!
After Complement Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

#success test_bag_complement_null_source OK

```



```

<terminated> Collections Debug [C/C++ Application] /mnt/hgf
#starting test_bag_complement_empty_source
Before Complement Source:
-----
Bag(0):
-----

Before Complement Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Complement Source:
-----
Bag(0):
-----

After Complement Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

#success test_bag_complement_empty_source OK

```



```

<terminated> Collections Debug [C/C++ Application] /mnt/h
#starting test_bag_complement_empty_result
Before Complement Source:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

Before Complement Target:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Complement Source:
-----
Bag(2):
-----
BagNode(value 2, 1), BagNode(value 1, 1)

After Complement Target:
-----
Bag(0):
-----

#success test_bag_complement_empty_result OK

```

```

Problems Tasks Console Properties Call Graph Search
<terminated> Collections Debug [C/C++ Application] /mnt/hgfs/cchet/Documents/

#starting test_bag_complement
Before Complement Source:
-----
Bag(5):
-----
BagNode(value 2, 2), BagNode(value 1, 3)

Before Complement Target:
-----
Bag(5):
-----
BagNode(value 2, 1), BagNode(value 1, 4)

After Complement Source:
-----
Bag(5):
-----
BagNode(value 2, 2), BagNode(value 1, 3)

After Complement Target:
-----
Bag(1):
-----
BagNode(value 1, 4)

#success test_bag_complement OK
#ending AllTests

=====
Meta information for MiniLib application
-----
Class hierarchy | Number of dynamic objects
-----+-----+-----+-----
               | created | deleted | still alive
-----+-----+-----+-----
Object         |      0 |      0 |      0
Collection     |      0 |      0 |      0
  List         |      0 |      0 |      0
    Set        |     27 |     27 |      0
      Bag      |     27 |     27 |      0
Node           |    108 |    108 |      0
  BagNode      |     61 |     61 |      0
String         |    116 |    116 |      0
Iterator       |      0 |      0 |      0
  ListIterator |     12 |     12 |      0
-----+-----+-----+-----
Number of classes: 10 | Summary: all objects deleted
=====

```