Project Documentation

class: Data Structures and Algorithms

Content:

A. Container of the abstract data type

1. Specification and interface

Iterator

Domain:

I ={it | it is an iterator over a Sparse Matrix with elements of type TElement }

Interface:

- init (it, sm)

  description: creates a new iterator for a Sparse Matrix

  precondition: sm is a Sparse Matrix

  postcondition: it ∈ I and it points to the first element in sm if sm is not empty or it is not valid

- getCurrent (it, e)

  description: return the current element from the iterator

  precondition: it ∈ I, it is valid

  postcondition: e ∈ TElement, e is the current element from it

- next (it)

  description: moves the current element from the sm to the next element or makes the iterator invalid if no elements are left.

  precondition: it ∈ I, it is valid

  postcondition: the current element from it points to the next element from the sparse matrix

- valid (it)

  description: verifies if the iterator is valid

  precondition: it ∈ I

  postcondition: will return true if it points to a valid element of the sparse matrix and false otherwise.

Sparse Matrix

<u>Domain:</u>

SM = {sm | sm is a sparse matrix with elements e = (l, c, v), where l ∈ Integer, c ∈ Integer and v ∈ TValue}

<u>Interface:</u>

- init (sm, noL, noC)
  - description: creates a new empty Sparse Matrix
  - precondition: noL ∈ Integer, noC ∈ Integer
  - postcondition: sm ∈ SM, sm is an empty sparse matrix
- destroy (sm)
  - description: destroys a sparse matrix
  - precondition: sm ∈ SM
  - postcondition: sm was destroyed
- noLines (sm)
  - description: the function will return the number of lines in the sparse matrix
  - precondition: sm ∈ SM
  - postcondition: the function will return an Integer representing the number of the lines
- noColumns (sm)
  - description: the function will return the number of columns in the sparse matrix
  - precondition: sm ∈ SM
  - postcondition: the function will return an Integer representing the number of the columns
- element (sm, line, column)
  - description: the function will return the element on the position (line, column)
  - precondition: sm ∈ SM, line ∈ Integer, column ∈ Integer

postcondition: v ∈ TValue, where v = v’, if there exist a tuple <line, column, v’> and the value “0” otherwise

- modify (sm, line, column, value)

  description: change the values of the element from line line and column column into value

  precondition: sm ∈ SM, line ∈ TValue, column ∈ TValue and value ∈ TValue

  postcondition: sm’ ∈ SM, if value from the possition <line, column> will become value

For the interface some of the function I used in the interface are private so I will enumerate then below:

- relation (a, b)

  description: The function is the relation that we use at the sparse matrix

  precondition: a ∈ TElement, b ∈ TElement

  postcondition: The function will return true is a>b or false otherwise

- add (sm, n, a)

  description: The function will actually add a pair to the sparse matrix

  precondition: sm ∈ SM, n ∈ Node ,a ∈ TElement

  postcondition: sm′∈ M, sm′= sm ∪ < line, column, value >

- minimum (sm, n)

  description: The function will return a not which is minimum after below the node n

  precondition: sm ∈ SM, n ∈ Node

  postcondition: minimum ← the minimum value from the tree below n

- remove (sm, n, line)

  description: The function will actually remove a pair from the sparse matrix

  precondition: sm ∈ SM, n ∈ Node ,k ∈ TValue

  postcondition: sm′∈ SM, sm′= sm \ < line, column, value >

- update (sm, line, column, value)

  description: the function that will actually change the value of a triple in the sparse matrix

  precondition: sm ∈ SM, line ∈ Integer, column ∈ Integer, value ∈ TValue

  postcondition: sm' ∈ SM, sm'= sm <line, column, value>

2. Representation of the abstract data type

- Representation

TElement:

line: integer

column: integer

value: string

Node:

info: TElement

left: ↑ Node

right: ↑ Node

SparseMatrix:

root: ↑ Node

noLines: integer

noColumns: integer

Iterator:

sm: ↑ SparseMatrix

s: stack<Node*>

currentNode: ↑Node

Pseudocode for every function in the iterator:

- **subalgorithm** init (it, sm) is:

```
[it].sm ← sm
@allocate Node nod
nod ← [it].[sm].root
while (not nod = NILL) execute
        [it].s.push(nod)
        nod ← [nod].left
end - while
if (not [it].s.empty()) then
        [it].currentNode ← [it].s.top()
else
        [it].currentNode ← NILL
end - if
```

end - subalgorithm

- **function** getCurrent(it) is:

```
getCurrent ← [it].[currentNode].info;
```

end - function

- **subalgorithm** next(it) is:

```
@allocate Node nod
nod ← [it].s.top()
[it].s.pop()
if (not [nod].right = NILL) then
        nod ← [nod].right
        while (not nod = NIL) execute
                [it].s.push(nod)
                nod ← [nod].left
        end - while
end - if
```

```
        if (not [it].s.empty()) then
                [it].currentNode ← [it].s.top()
        else
        [it].currentNode ← NILL
        end - if
end - subalgorithm
```

- **function** valid(it) is:

```
        if ([it].currentNode = NILL) then
                valid ← false
        else
                valid ← true
        end - if
end - function
```

Pseudocode for every function in the container:

- **subalgorithm** init(sm, noLines, noColumns) is:

```
        [sm].root ← NILL
        [sm].noC ← noColumns
        [sm].noL ← noLines
end - subalgorithm
```

- **function** noLines (sm) is:

```
        noLines ← [sm].noL
end - function
```

- **function** noColumns (sm) is:

```
        noColumns ← [sm].noC
end - function
```

```
○ function element (sm, line, column) is:
    @ allocate TElement something
    something.line ← line
    something.column ← column
    something.value ← "0"
    @allocate node currentNode
    currentNode ← sm.root
    while (not [currentNode] = NIL)
        if ([[currentNode].info].column = column and
                                   [[currentNode].info].line = line)
        if (not relation([currentNode].info, something))
            currentNode ← [currentNode].right
        else
            currentNode ← [currentNode].left
        end - if
    end - while
    if (currentNode = NILL)
        element ← "0"
    end - if
    element ← [[currentNode].info].value
end - function
○ function add(sm, node, e)
    if node = NIL then
        @allocate(node)
        [node].info ← e
        [node].left ← NIL
        [node].right ← NIL
    else if relation([node].info, e) then
        add ([node].left, e)
      else
        add ([node].right, e)
      end - if
    end - if
end - function
```

```
○ function update (sm, line, column, value) is:
    @ allocate TElement something
    something.line ← line
    something.column ← column
    something.value ← "0"
    @allocate node currentNode
    currentNode ← sm.root
    while (not [currentNode] = NIL)
        if ([[currentNode].info].column = column and
                                        [[currentNode].info].line = line)
        if (not relation([currentNode].info, something))
            currentNode ← [currentNode].right
        else
            currentNode ← [currentNode].left
        end - if
    end - while
    if ([[currentNode].info].column = column and [[currentNode].info].line
                                                                    = line)
        [[currentNode].info].value = value;
    end - if
end - function

○ function minimum(sm, n) is:
    @allocate Node currentNode
    currentNode ← n
    while (not [currentNode].left = NIL)
        currentNode ← [currentNode].left
    end - while
    minimum ← currentNode
end - function
```

```
function remove(sm, n, line) is:
    @allocate int isRoot
    isRoot ← 0
    if (n == NILL) then
        removeRec ← n else
    if (line < [n].info.line) then
        [n].left ← removeRec([n].left, line)
    else if (line > [n].info.line) then
        [n].right ← removeRec([n].right, line)
    else:
        if ([n].left = NIL and [n].right = NIL) then
            if ( n = [sm].root)
            [sm].root = NIL
            @delete n
            n ← NILL
        else if ([n].right = NIL) then
            if (n = [sm].root) then
                isRoot ← 1
                @allocate Node aux
                aux ← n
                n ← [n].left
                delete aux
                if (isRoot = 1) then
                    [sm].root ← n
            else if ([n].left = NIL) then
                if (n = [sm].root) then
                    isRoot ← 1
                    @allocate Node aux
                    aux ← n
                    n ← [n].right
                    delete aux
                    if (isRoot = 1) then
                        [sm].root ← n
        else
            if (n = [sm].root) then
```

```
                    isRoot ← 1
                    @allocate Node aux
                    aux ← [sm].minimum([n].right)
                    [n].info = [aux].info
                    [n].right = removeRec([n].right, [aux].info.line)
                    if (isRoot = 1) then
                        [sm].root ← n
                end - if
            end - if
        removeRec ← n
end - function
```

- **subalgorithm** modify (sm, line, column, value)

```
        @allocate string oldValue
        oldValue ← element(line, column)
        @allocate TElement somehting
        [something].line ← line
        [something].column ← column
        [something].value ← value
        if (oldValue = "0")
            if (value = "0")
                @break
            else
                add(sm.root, something)
            end - if
        else
            if (value = "0")
                remove(sm.root, line)
            else
                update(line, column, value)
            end - if
        end - if
end - subalgorithm
```

- **function** iterator (sm) is:
    @ allocate Iterator{sm} to it
    iterator ← it

end - function

3. Complexity of the operations

Complexity of all the functions

A) Container

- ~ **init** has the general complexity Θ(1)
- ~ **destroy** has the general complexity Θ(1)
- ~ **relation** has the general complexity Θ(1)
- ~ **noLines** has the general complexity Θ(1)
- ~ **noColumns** has the general complexity Θ(1)
- ~ **element** has the general complexity Θ(n)
- ~ **add** has the general complexity Θ(n)
- ~ **update** has the general complexity Θ(n)
- ~ **minimum** has the general complexity Θ(n)
- ~ **remove** has the general complexity Θ(n)
- ~ **modify** has the general complexity Θ(1)
- ~ **iterator** has the general complexity Θ(1)

B) Iterator

- ~ **init** has the general complexity Θ(n)
- ~ **getCurrent** has the general complexity Θ(1)
- ~ **next** has the general complexity Θ(n)
- ~ **valid** has the general complexity Θ(1)

Computed complexity for the element function

Best Case:

The best case is when the element that we are searching is
first position in our binary search tree, having then the complexity Θ(1). Just the first number is checked, no matter how large the binary tree is.

Worst Case:

The worst case possible is that the element we are searching is actually on the last position on the binary tree, then the function will have the complexity $\Theta(n)$. We have to check all numbers from the binary tree.

Average Case:

The average case is computed by the formula: $\sum_{I \in D} P(I) \cdot E(I)$ where:

- D is the domain of the problem, the set of every possible input that can be given to the algorithm, in our case {a..z}x{a..z} because k can takes values from a to z and the same v.
- I is the input data
- P(I) is the probability that we will have I as input
- E(I) is the number of operation performed by the algorithm for input I

For our example D would be the set of all possible binary trees with n leafs:

For our example I could be a subset of D in which:

- One I represents all the binary trees where the first element being the one that we are looking for
- One I represents all the binary trees where the second element is the one that we are looking for ...

P(I) is usually considered equal for every I

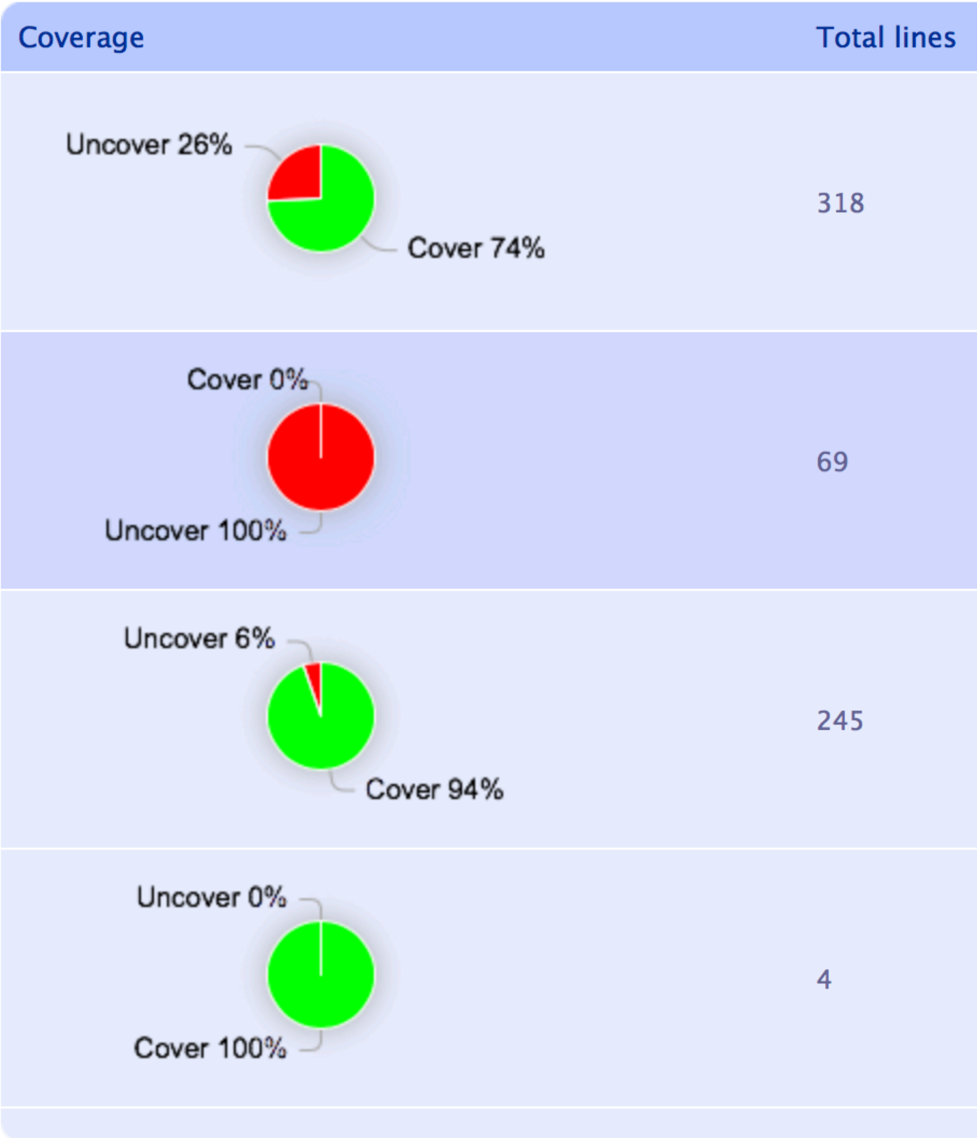
So the complexity would be something like:

$$\sum_{i=1}^{n} (n+10) = 11 + 12 + 13 + \ldots = \text{(aprox) } n$$

So the average case is actually O(n)

4. Test Coverage and Tests

Code Coverage Proof



The hole project coverage

The ui coverage

The Sparse Matrix file coverage

The main coverage

Functions Used For Testing

For testing all the function in the sparse matrix and iterator I've made a class TestApplication which contains a public function TestAll that calls other functions that test each functionality individually.

```
bool rel(TElement a, TElement b) {
	if (a.line > b.line) return true;
	else if (a.line == b.line)
		if (a.column > b.column) return true;
	return false;
}

void TestApplication::testAll() {
	testNoLines();
	testNoColumns();
	testElement();
	testModify();
	testRelation();
	testIterator();
}

void TestApplication::testNoLines() {
	SparseMatrix sm{ 1,3 };
	assert(sm.noLines() == 1);
}
void TestApplication::testNoColumns() {
	SparseMatrix sm{ 1,3 };
	assert(sm.noColumns() == 3);
}
void TestApplication::testElement() {
	SparseMatrix sm{ 4,4 };
	sm.modify(4, 4, "S");
	sm.modify(3, 1, "S");
	sm.modify(4, 1, "S");
	sm.modify(5, 1, "S");
	assert(sm.element(4, 4) == "S");
	assert(sm.element(3, 1) == "S");
	assert(sm.element(4, 1) == "S");
```

```
    assert(sm.element(5, 1) == "S");

}
void TestApplication::testModify() {
    SparseMatrix sm{ 10,10 };
    sm.modify(3, 1, "Buna");
    sm.modify(2, 1, "Holla");
    sm.modify(4, 1, "Buna ce mai zici");
    sm.modify(4, 1, "Ce???");
    assert(sm.element(4, 1) == "Ce???");
    sm.modify(6, 2, "okrrr");
    sm.modify(5, 1, "no");
    sm.modify(6, 1, "si ...");
    sm.modify(6, 1, "0");
    sm.modify(4, 1, "0");
    sm.modify(3, 1, "0");
    sm.modify(6, 2, “0");
    assert(sm.element(6, 2) == “0”);
    assert(sm.element(2, 1) != “0”);
}

void TestApplication::testRelation() {
    TElement test1, test2;
    test1.line = 2;
    test2.line = 1;
    test1.column = 3;
    test2.column = 2;
    test1.value = "0";
    test2.value = "0";
    assert(rel(test1, test2) == true);
    test2.line = 2;
    assert(rel(test1, test2) == true);
    test1.column = 1;
    assert(rel(test1, test2) == false);
}
```

```
void TestApplication::testIterator() {
	SparseMatrix sm{ 5,5 };
	Iterator it2 = sm.iterator();
	assert(it2.valid() == false);
	sm.modify(3, 1, "S");
	sm.modify(4, 1, "S");
	sm.modify(2, 1, "S");
	Iterator it = sm.iterator();
	assert(it.valid() == true);
	assert(it.getCurrent().line == 2);
	it.next();
	assert(it.getCurrent().line == 3);
	it.next();
	it.next();
	assert(it.valid() == false);
}
```

B. Application

1. Problem Statement

The problem that was assigned for me to solve:

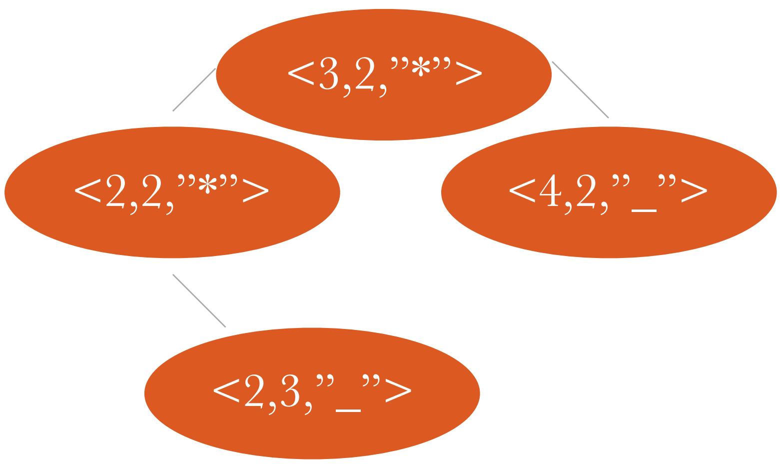
27. ADT SparseMatrix – representation using <line, column, value> triples (value ≠ 0). Implementation on a binary search tree.

The solution that I thought for solving the problem:

I would like to recreate the **Battleship** game which is a guessing game on which the players' fleets of ships (including battleships) are marked. The locations of the fleet are concealed from the player. Player turns calling "shots" at the games ships, and the objective of the game is to destroy the all the games board ships.

The reason why I chose this method to solve the problem is because the hole game is played on a matrix. At the beginning there are lots of empty spaces so because of that the sparse matrix is the perfect abstract data type for solving this problem, also because of the data type (binary search tree) the search will be so much faster than searching element by element. Down below I putted an example of how things will be stored in the app.

	1	2	3	4	5
1	0	0	0	0	0
2	0	*	_	0	0
3	0	*	0	0	0
4	0	_	0	0	0
5	0	0	0	0	0



2. Solutions to the chosen problem

Representation of the User Interface Class

Ui:

sm: ↑ SparseMatrix

sm1: ↑ SparseMatrix

Interface of the operations

- constructor (ui, sm, sm1)

  description: the function creates an object ui

  precondition: sm ∈ SM and sm1 ∈ SM

  postcondition: ui ∈ Ui

- run (ui)

  description: the function keeps the main loop for the application

  precondition: ui ∈ Ui

- constructor (ui, sm)

  description: creates a configuration for a board for the game

  precondition: sm ∈ SM, ui ∈ Ui

  postcondition: sm' = sm + <configurations>

- printMatrixSM (ui, sm1)

  description: the function will print the board for the game

  precondition: sm1 ∈ SM and ui ∈ Ui

- readIntegerNumber (ui, input)
  description: the function read something from the keyboard
  precondition: ui ∈ Ui
  postcondition: input will be the information read from the keyboard

Implementation of operations

- **subalgorithm** constructor (ui, smParam, sm1Param) is:
  [ui].sm = smParam
  [ui].sm1 = sm1Param

end - subalgorithm

- **subalgorithm** printMatrixSM (ui) is:
  for i ← 1 to 10, i++ execute
    for j ← 1 to 10, j++ execute
      @print ui.sm.element(i, j)
    end - for
  @print a new line
  end - for

end - subalgorithm

- **function** configurationBoard (ui) is:
  [[ui].sm.]modify(4, 4, "S")
  [[ui].sm.]modify(3, 1, "S")
  [[ui].sm.]modify(4, 1, "S")
  [[ui].sm.]modify(5, 1, "S")
  [[ui].sm.]modify(8, 3, "S")
  [[ui].sm.]modify(8, 3, "S")
  [[ui].sm.]modify(8, 4, "S")
  [[ui].sm.]modify(8, 5, "S")
  [[ui].sm.]modify(1, 8, "S")
  [[ui].sm.]modify(2, 8, "S")
  [[ui].sm.]modify(3, 8, "S")

```
    [[ui].sm.]modify(4, 8, "S")
end - function

○ function readIntegerNumber (ui, message) is:
    @ char s[16];
    @ int res
    @ int flag
    @ int r
    while (flag = 0) execute
        @ print message
        @ read from keyboard
        @ r = sscanf(s, res)
        flag = (r = 1)
        if flag = 0 then
            @ print Error reading number
    end - while
    readIntegerNumber ← res
end - function

○ subalgorithm run ( ui ) is:
    @ print Rules:
    @ print 1. There are 2 ships made out of 3 spaces, 1 made of one, and 1
                                                              made of four
    @ print 2. If you miss then the character _ will be displayed
    @ print 3. If you hit a ship the character * will be displayed
    @ print Let the games begins
    [ui].configurationBoard
    @int hits = 0
    while 1 execute:
        @ int line
        @ print Give a line:
        line ← [ui].readIntegerNumber("")
        @ int column
        @ print Give a column
```

```
        column ← readIntegerNumber("")
        if (line < 1 or line > 10 or column < 0 or column > 10) then
            @ print Wrong input! please insert values between [1, 10]
        else
            if [[ui].sm].element(line, column) = "S" then
                if [[ui].sm1].element(line, column) = "0" then
                    [[ui].sm1].modify(line, column, "*")
                    hits ← hits + 1
                else
                    @print You already hit this boat …
                end - if
            else
                [[ui].sm1].modify(line, column, "_")
            end - if
            [ui].printMatrixSM
        end - if
        if hits = 11 then
            @break
    end - while
    @print Congratulation
end - subalgorithm
```

3. Complexity for the operations

~ **constructor** has the general complexity Θ(1)

~ **run** has the general complexity Θ(1)

~ **configurationBoard** has the general complexity Θ(1)

~ **printMatrixSM** has the general complexity Θ(n^2)

~ **readIntegerNumber** has the general complexity Θ(1)