Data *Structures*

Project: Sparse Array and Matrix

Mostafa S. Ibrahim
Teaching, Training and Coaching since more than a decade!

Artificial Intelligence & Computer Vision Researcher
PhD from Simon Fraser University - Canada
Bachelor / Msc from Cairo University - Egypt
Ex-(Software Engineer / ICPC World Finalist)

Problem #1: Sparse 1D Array

- In some applications, we might want to represent an array with indices very huge (e.g. 10^8), however, most of it are just zeros (e.g. 95%)
- Creating such huge arrays is very time & memory harmful with no return
  - Complete: 0 0 20 0 40 50 0 70 0 0
  - Better: (50, 5), (20, 2), (70, 7), (40, 4) = (value, idx) list
- A better idea is to represent such arrays using a linked list
- Create a linked list: **ArrayLinkedList**
  - Use a doubly linked list
- It represents a sparse array. Provide the following functions
  - Set and Get positions, Print array, add arrays
- *A useful application: Polynomial representation (e.g. $2X^{60} + 17X^{1500}$)*

Problem #1: Sparse 1D Array

```
ArrayLinkedList array(10);   // length 10
array.set_value(50, 5);
array.set_value(20, 2);
array.set_value(70, 7);
array.set_value(40, 4);
array.print_array();
// 0 0 20 0 40 50 0 70 0 0
array.print_array_nonzero();
// 20 40 50 70
cout << array.get value(7) << "\n"; // 70
```

```
ArrayLinkedList array2(10);
array2.set_value(1, 4);
array2.set_value(3, 7);
array2.set_value(4, 6);

array.add(array2);
array.print_array();
// 0 0 20 0 41 50 4 73 0 0
```
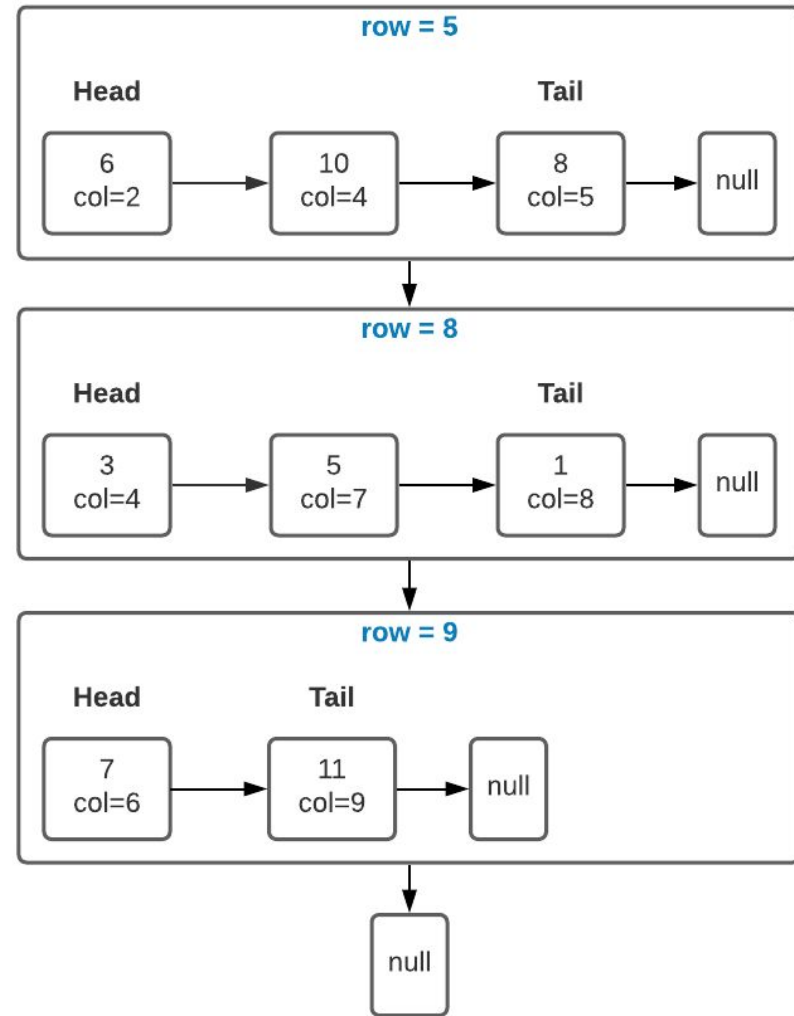
Problem #2: Sparse Matrix (2D Array)

- A more severe/common case is a sparse matrix where most of it are zeros
- Similarly, we will implement SparseMatrix to act like 2D array
- Design wise:
  - Each row in the sparse matrix, is what we actually implemented in the 1D case
  - Now we can think of sparse matrix as linked list of linked list
    - 2 linked lists
    - First: the 1D array linked list
    - Second: linked list, the data of each node is a 1D linked list
    - Again use a doubly linked list

Problem #2: Sparse Matrix

- Assume we have matrix 20x20
- However we have only the following cells
  - Arr[5][2] = 6, Arr[5][4] = 10, Arr[5][5] = 8
  - Arr[8][4] = 3, Arr[8][7] = 5, Arr[8][8] = 1
  - Arr[9][6] = 7, Arr[9][9] = 11
- We better create list of 3 connected rows
  - Each row, has the content at specific columns
- In right: Parent linked list of 3 nodes
  - Inside each node, a linked list of its columns
  - For simplification: SSL is used

Problem #2: Sparse Matrix

```
SparseMatrix mat(10, 10);
mat.set_value(5, 3, 5);
mat.set_value(7, 3, 7);
mat.set_value(2, 3, 2);
mat.set_value(0, 3, 2);
mat.set_value(6, 5, 6);
mat.set_value(4, 5, 4);
mat.set_value(3, 7, 3);
mat.set_value(1, 7, 1);
//mat.set_value(1, 70, 1);
mat.print_matrix();
mat.print_matrix_nonzero();
```

```
Print Matrix: 10 x 10
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 5 0 7 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 4 0 6 0 0 0
0 0 0 0 0 0 0 0 0 0
0 1 0 3 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
```

Problem #2: Sparse Matrix

```
SparseMatrix mat2(10, 10);
mat2.set_value(5, 1, 9);
mat2.set_value(6, 3, 8);
mat2.set_value(9, 9, 9);
mat.add(mat2);
mat.print_matrix_nonzero();
```

```
Print Matrix: 10 x 10
0 5 7
4 6
1 3

Print Matrix: 10 x 10
5
0 5 7 6
4 6
1 3
9
```

"Acquire knowledge and impart it to the people."

"Seek knowledge from the Cradle to the Grave."