CSI 2103: Data Structures

HW Assignment 2

Yonsei University
Spring 2022

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Array and Doubly Linked List

- Aims:
  - Study two data structures: array and doubly linked list (DDL)
  - See how a digital image can be stored in such data structures
  - Implement algorithms that transform the images by manipulating the data structures
- Two parts:
  - Part 1: Toy example of converting a 2D array into 2D doubly linked list
  - Part 2: Resizing image

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Simple Node Class

```
class Node:
    """ Node class
            up
             |
    left - data - right
             |
           down
    """

    def __init__(self, data):
        self.data = data
        self.right = None
        self.left = None
        self.up = None
        self.down = None
```

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Image as a 2D array

0	0	0	0	255	0
100	100	100	0	255	0
100	100	100	0	255	0
100	100	100	0	255	0
0	0	0	0	255	0

image: np.ndarray (numpy n-dimensional array)
image_matrix.shape[0] shows the "height" (5 in above example)
image_matrix.shape[1] shows the "width" (6 in above example)

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Part 1

- In this simple toy example, you will convert a 2D array to a 2D doubly linked list. Several functions have to be implemented at this stage:
  - constructDoublyLinkedListRecursiveStep
  - constructDoublyLinkedListLoop

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2D Array (Matrix) with numpy.ndarray

arr: numpy.ndarray
arr.shape[0]: first dimension size ("height")
arr.shape[1]: second dimension size ("width")
arr[y][x]: element at row "y" and column "x"

		column			
		x = 0	x = 1	x = 2	x = 3
row	y = 0	5	4	7	10
	y = 1	6	12	1	9
	y = 2	8	2	3	11

```
print(arr.shape[0])     # 3
print(arr.shape[1])     # 4
print(arr[0][0])        # 5
print(arr[2][3])        # 1
print(arr[2,3])         # also 1
```

Randomly generated 3x3 2D array

```
>> N = 3
>> arr = np.random.randint(0, 10, size=(N, N))
>> print(arr)
[[5  4  7]
 [9  6  3]
 [7  6  9]]

>> print(type(arr))
<class 'numpy.ndarray'>
```

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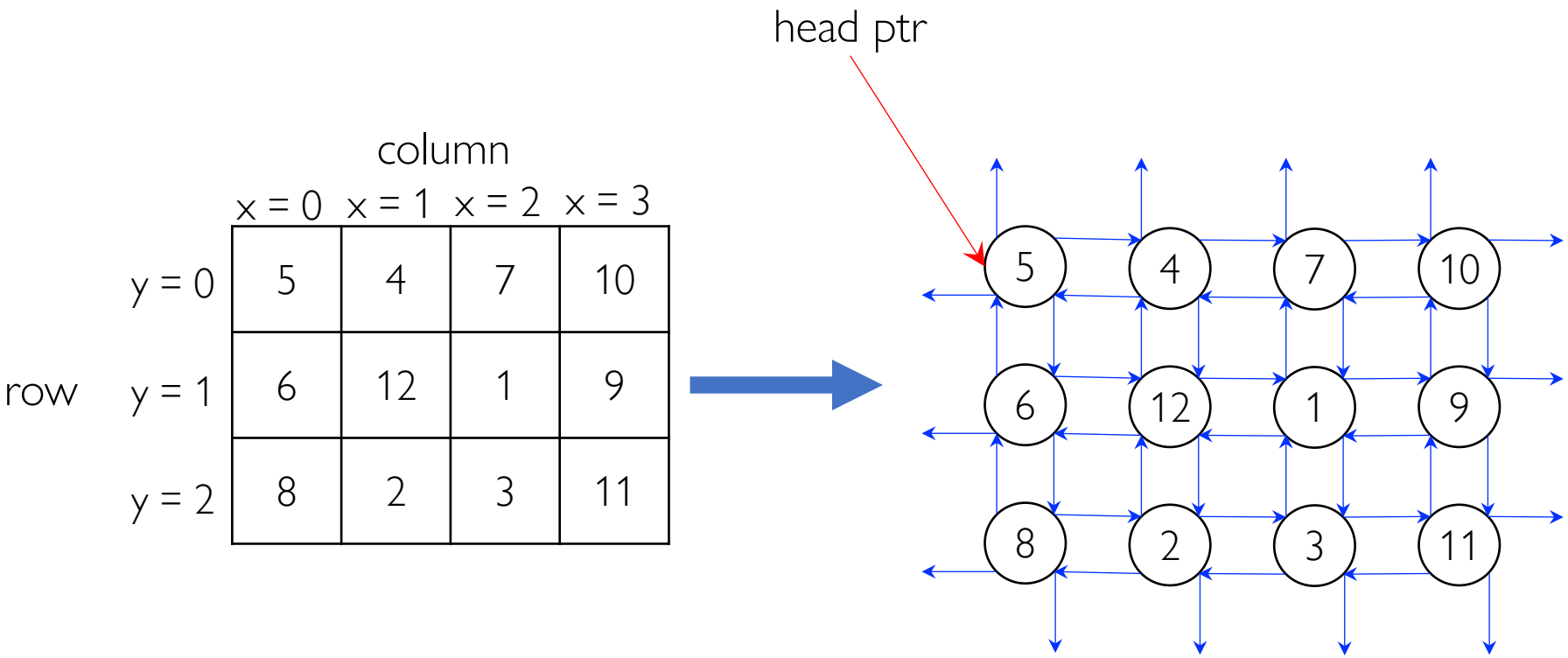
2D Array to 2D Doubly Linked List



dll_rec = constructDoublyLinkedListRecursion(arr)
dll_loop = constructDoublyLinkedListLoop(arr)

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constructDoublyLinkedListLoop

- input: arr (2D array to turn into a 2D DLL)
- output: top_left_ptr (head pointer to the top left node of the 2D DLL)

column

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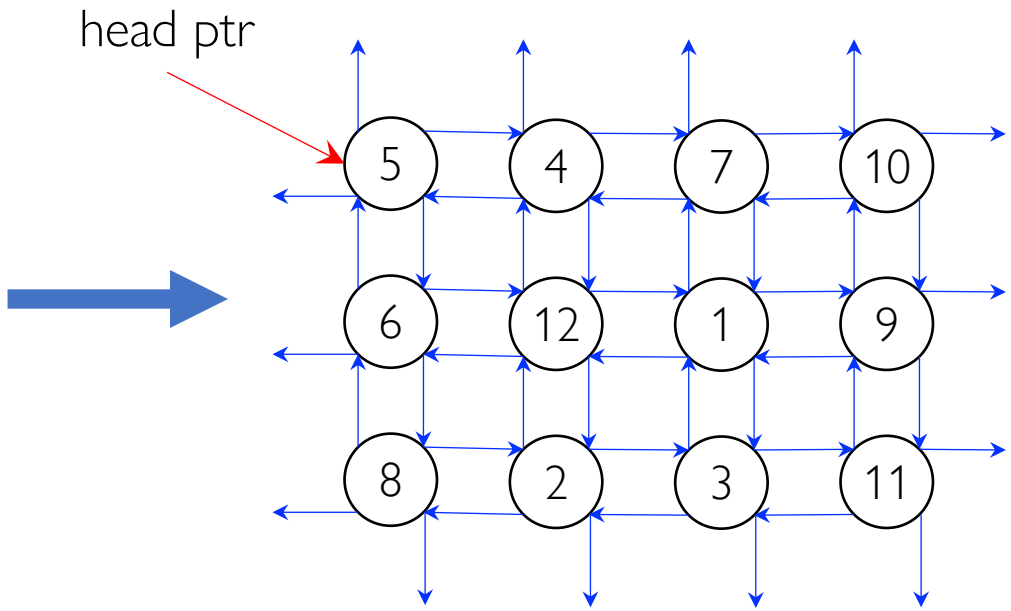

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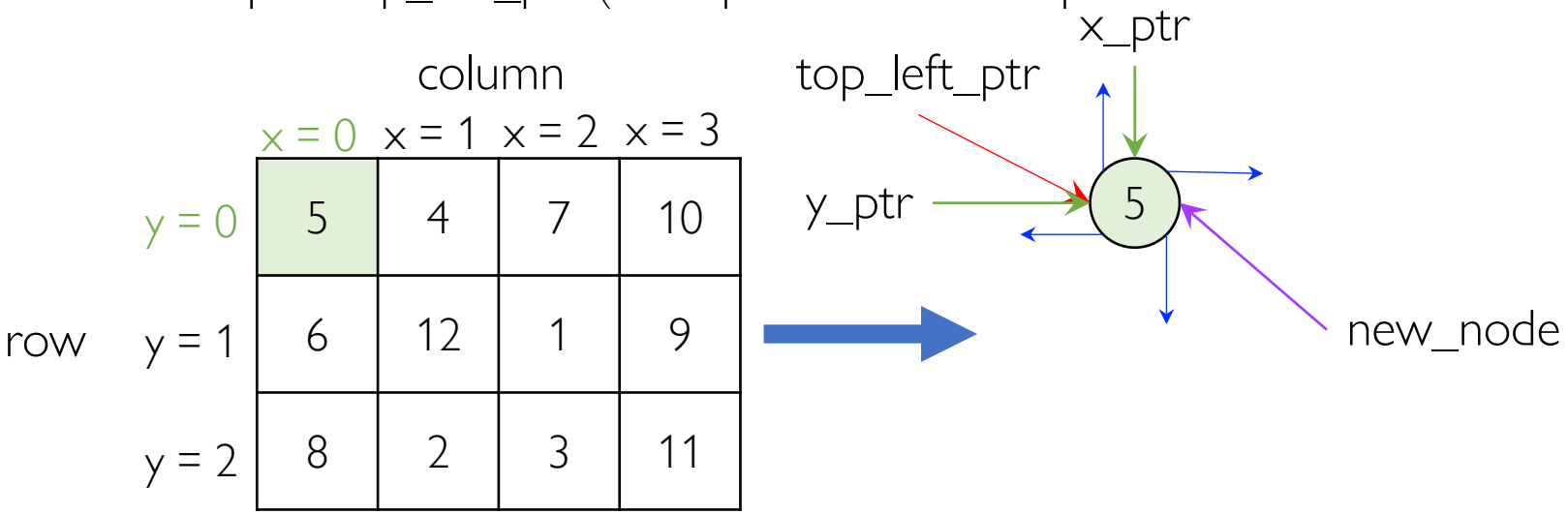

new_node = Node(arr[y,x])

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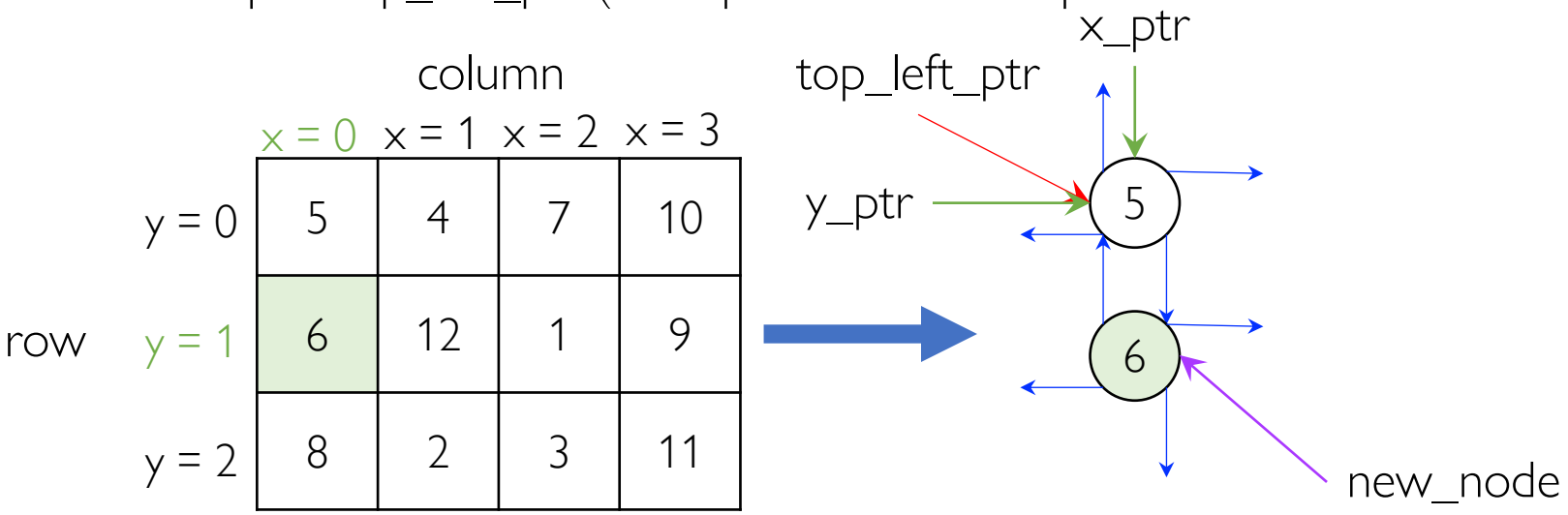

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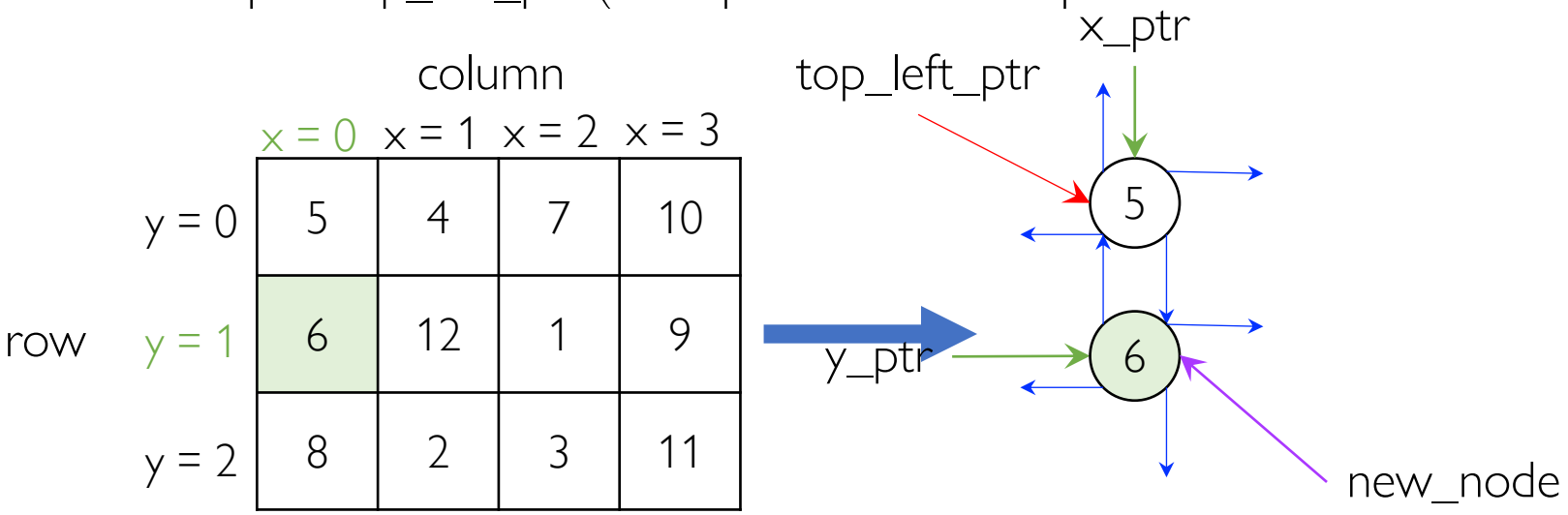

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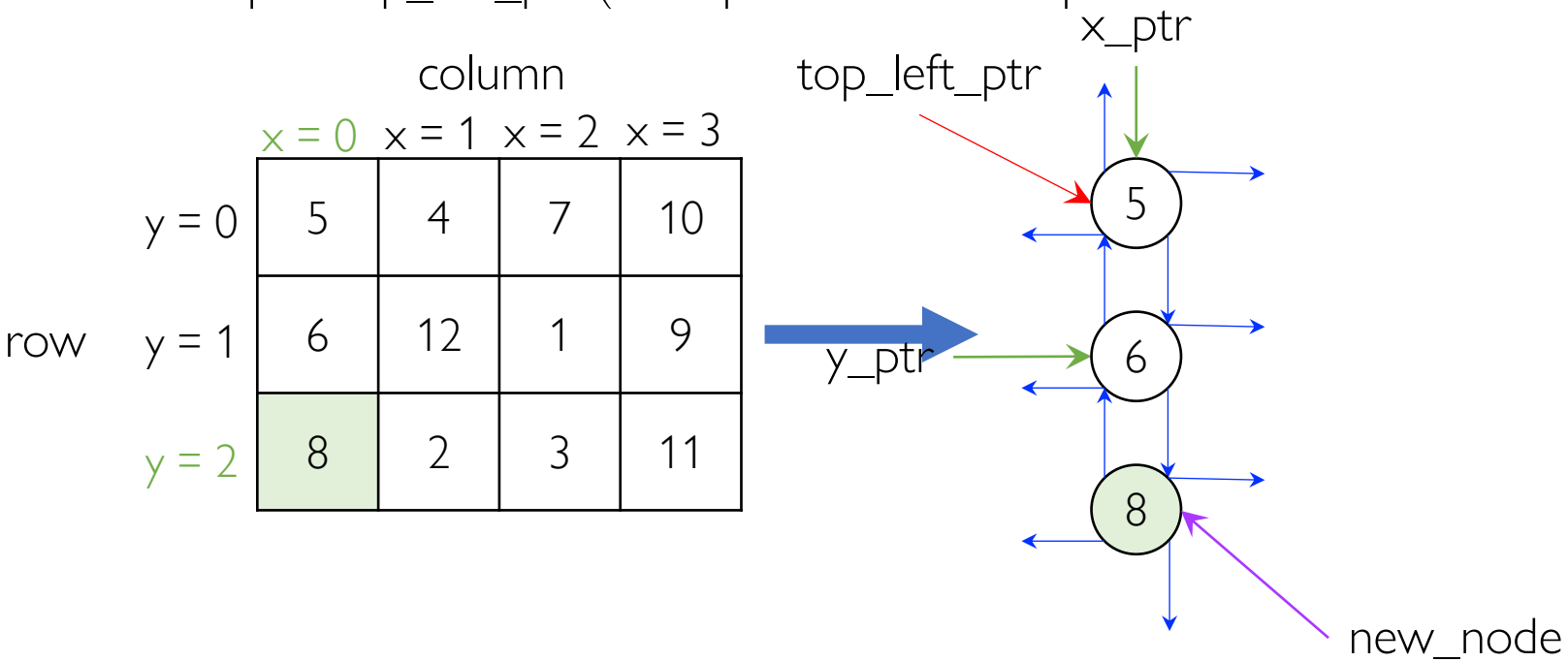

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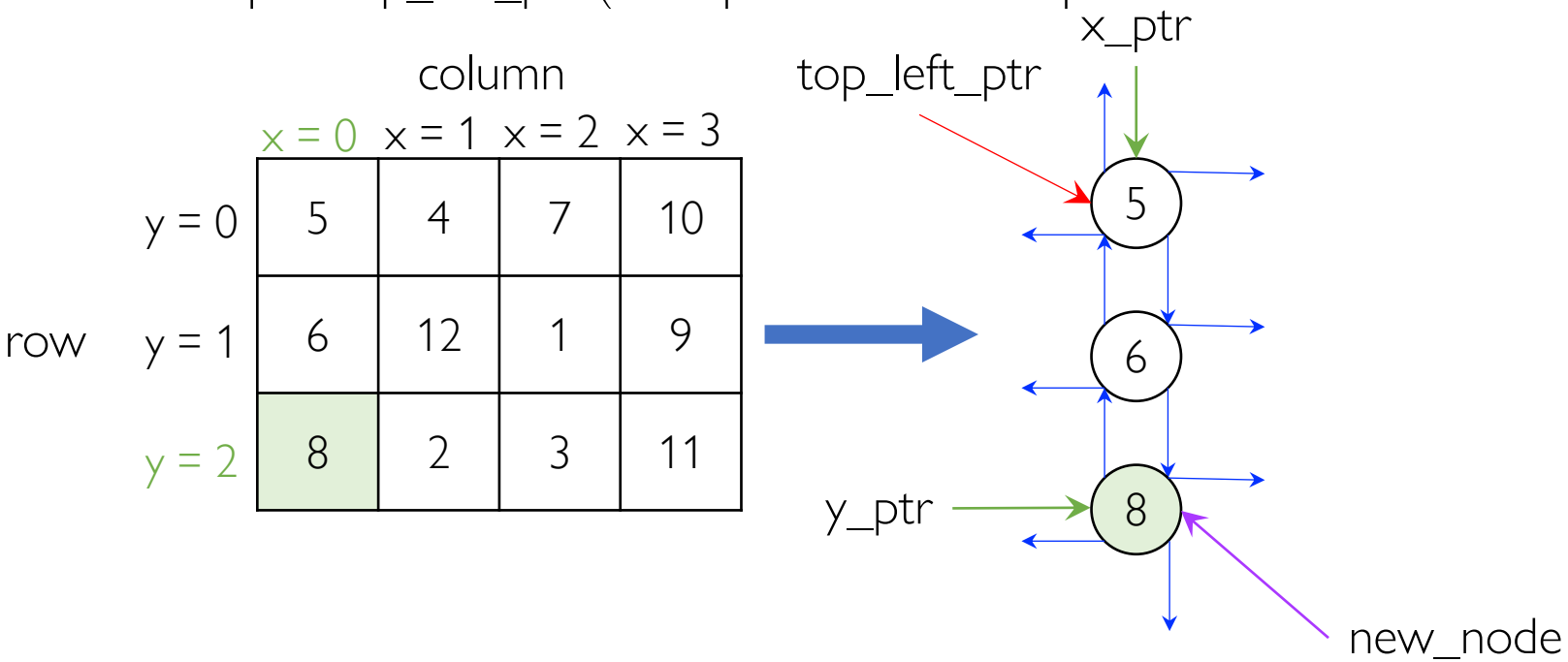

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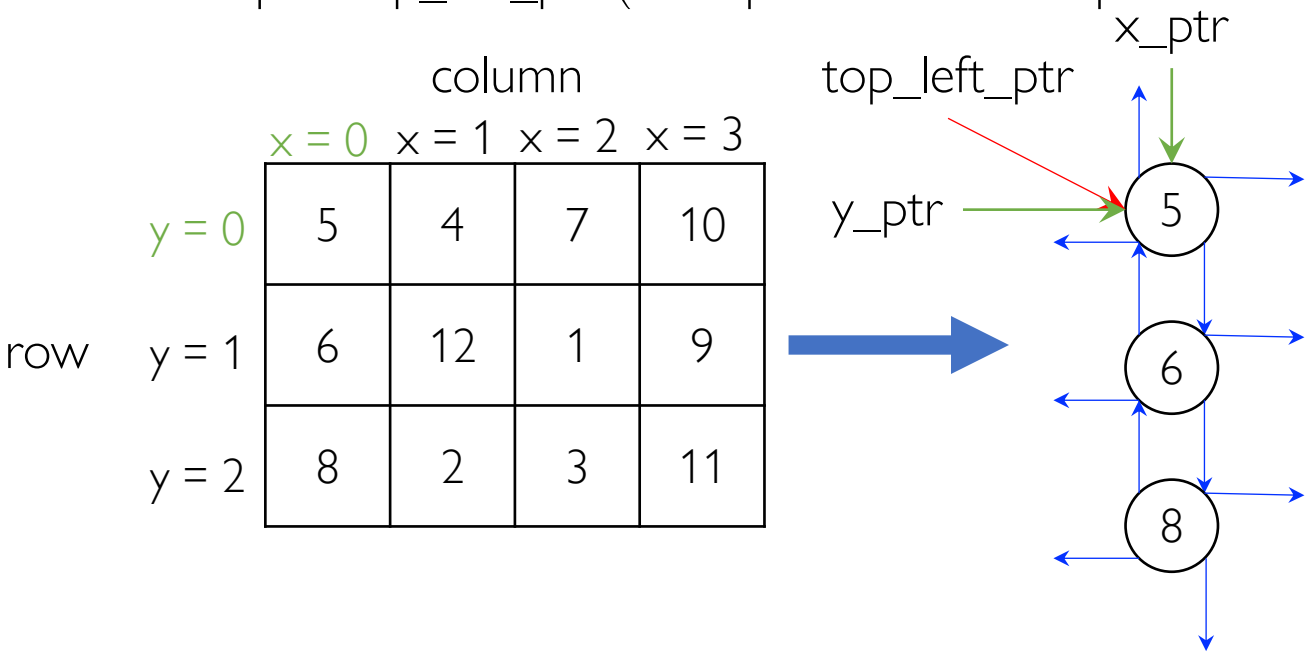

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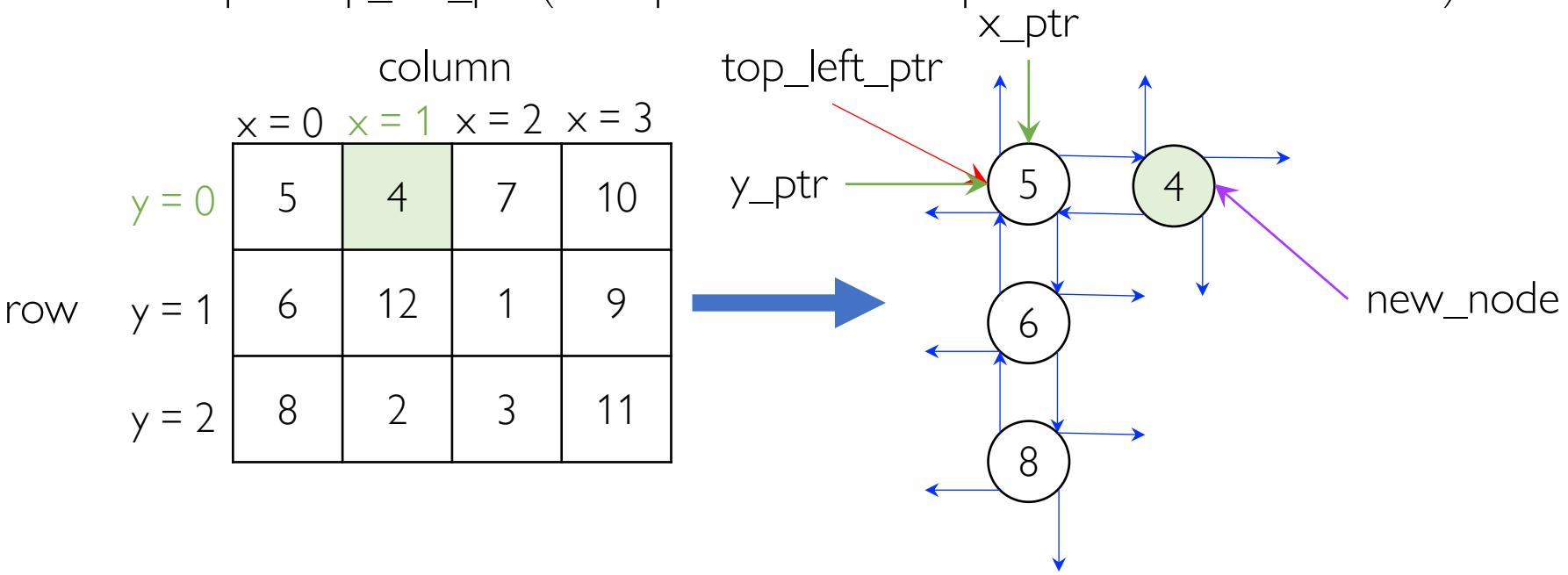

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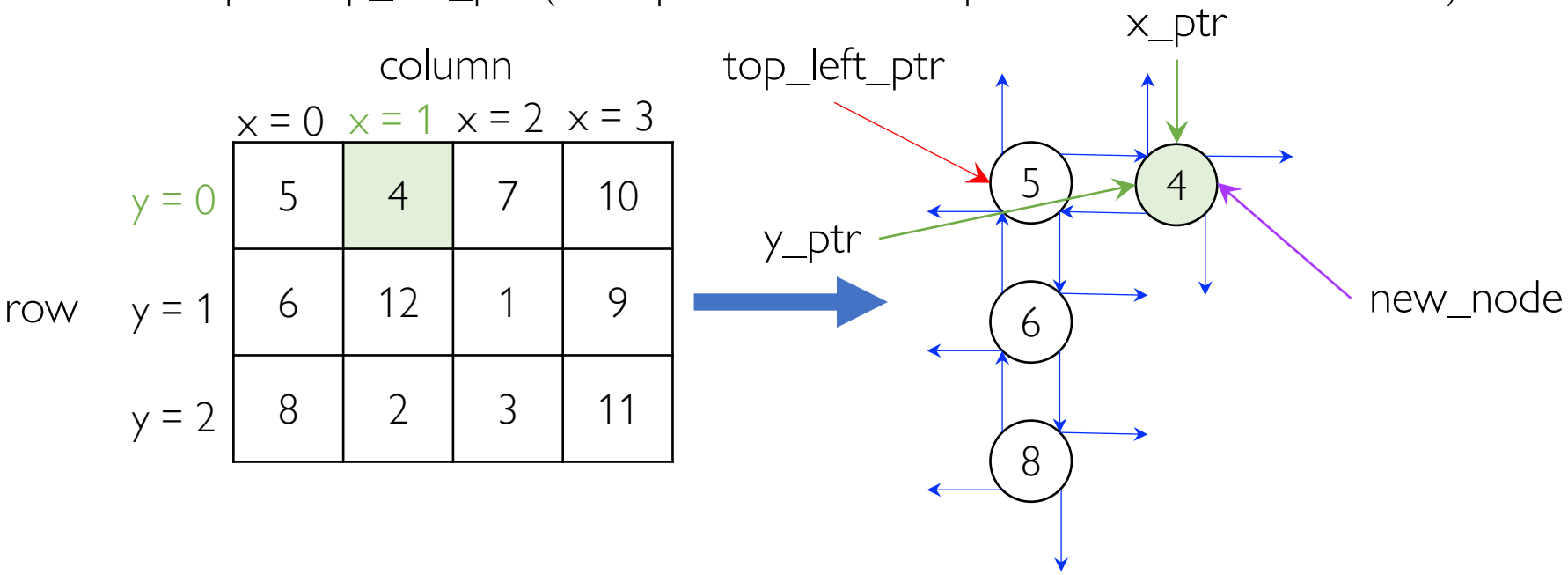

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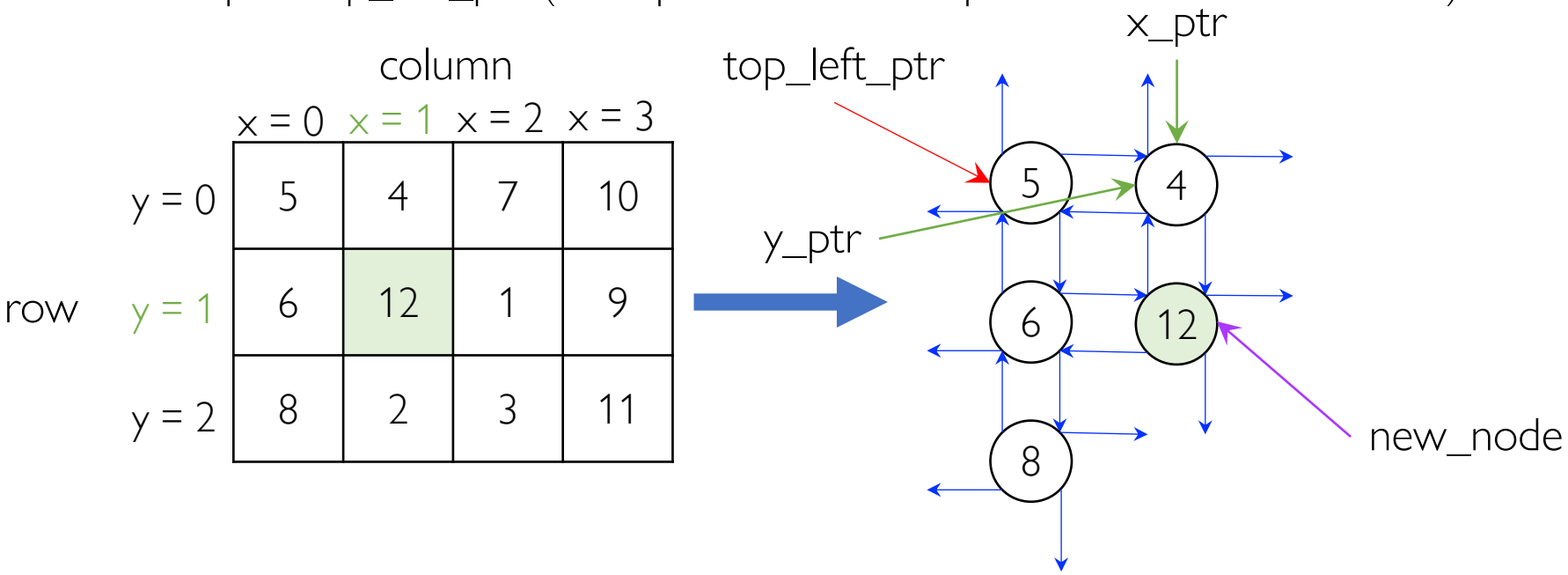

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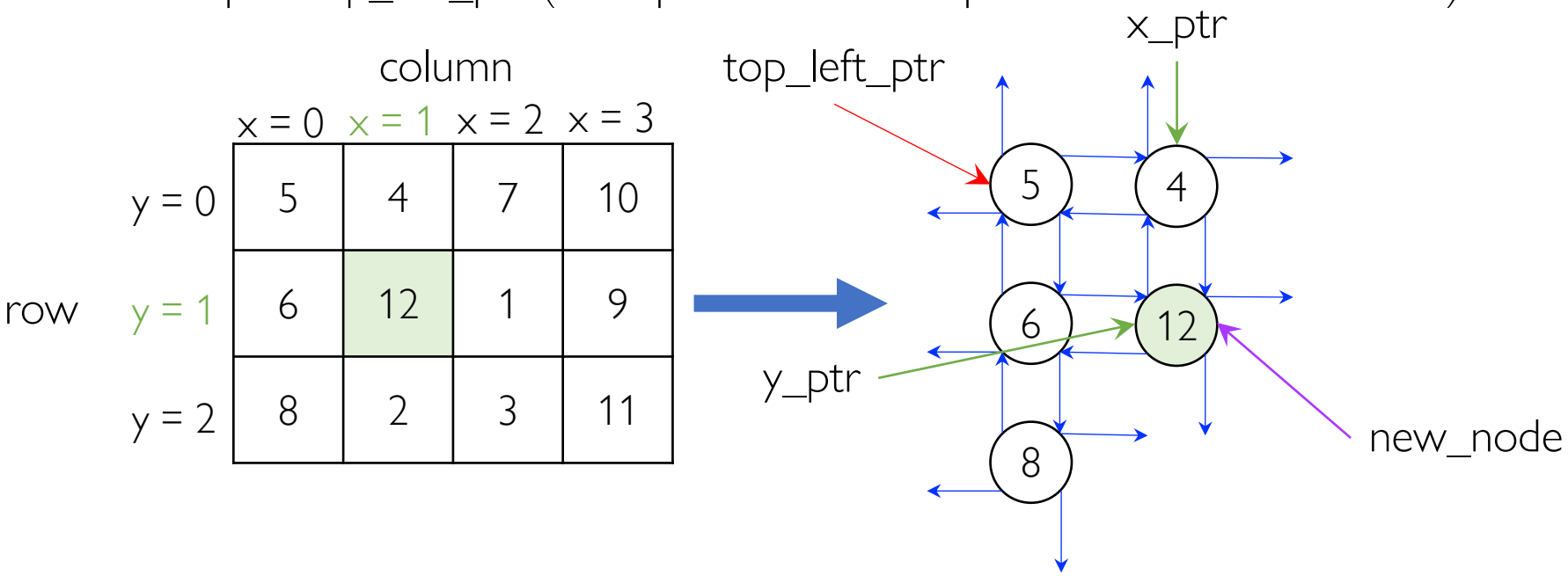

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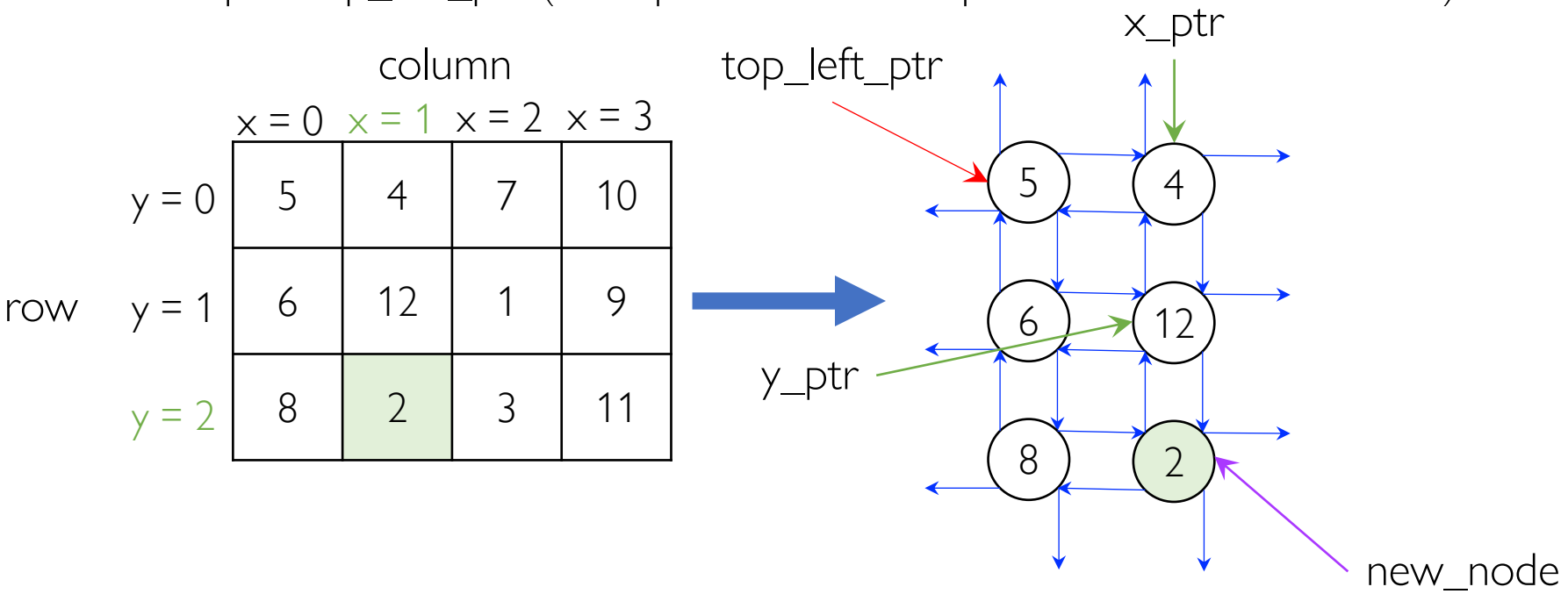

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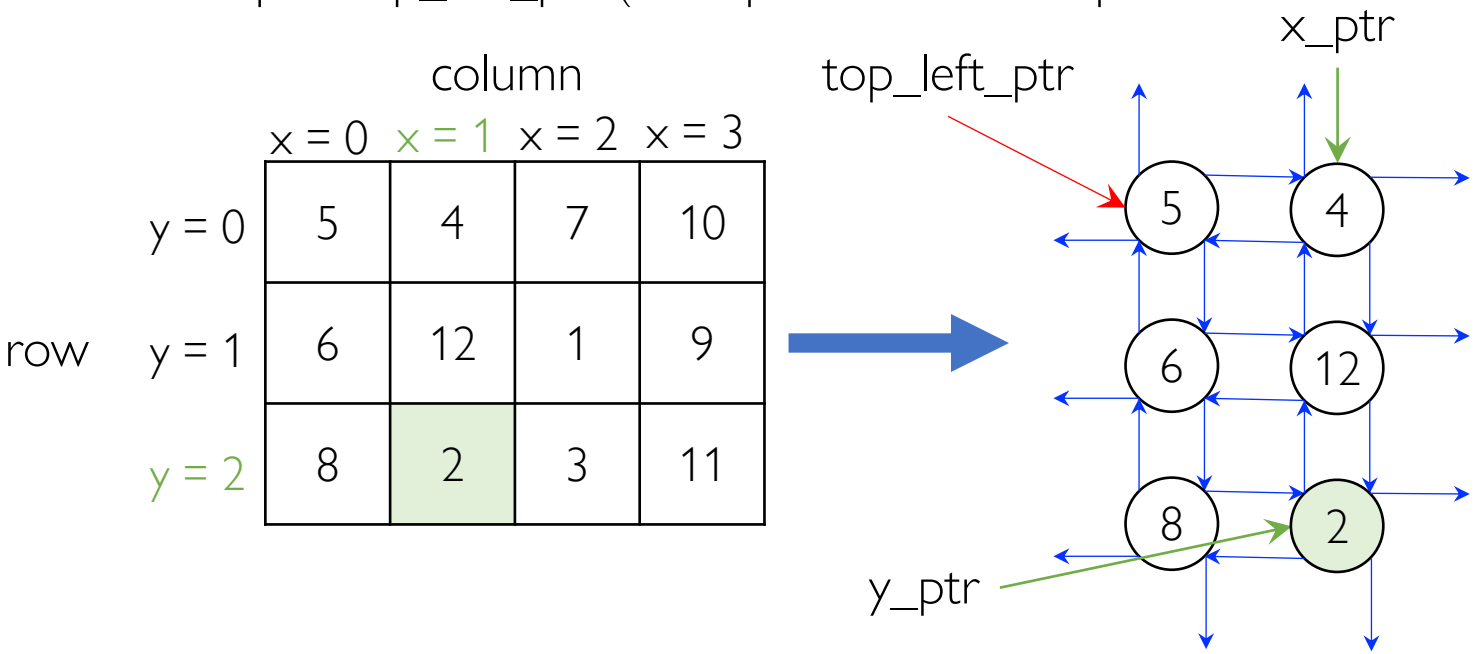

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constructDoublyLinkedListRecursion

```
def constructDoublyLinkedListRecursion(arr):
    """ Converts a 2D array into a 2D doubly linked list by calling
    the recursee constructDLLRecursiveStep.

    input:
        arr: 2D array to turn into a 2D DLL

    output:
        head (top left node) of the 2D DLL of the input arr.
    """
    return constructDLLRecursiveStep(arr, 0, 0, None)
```

- Often times, the main function is not actually recursive.
  - `constructDLLRecursiveStep` only takes arr, but this is not enough to perform recursive operations
- The actual recursive step (`constructDLLRecursiveStep`)is called as a separate function to include additional arguments

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constructDLLRecursiveStep

```
def constructDLLRecursiveStep(arr, y, x, curr):
    """ Recursively construct the 2D DLL from the given array.
    This is the "recursee" of constructDoublyLinkedListRecursion.

    input:
        arr: The 2D array to construct the 2D DLL from.
        y: y-coordinate of the array to get the value from.
        x: x-coordinate of the array to get the value from.
        curr: The current node to connect the new node from.

    output:
        new_node: The newly created node which connects to curr node.
    """

    Base case

    Operations

    Recursive Calls
```

arr: always need to pass in arr

y and x: keep track of the array indices you work on in each recursive step

curr: the current node pointer within the DLL being constructed

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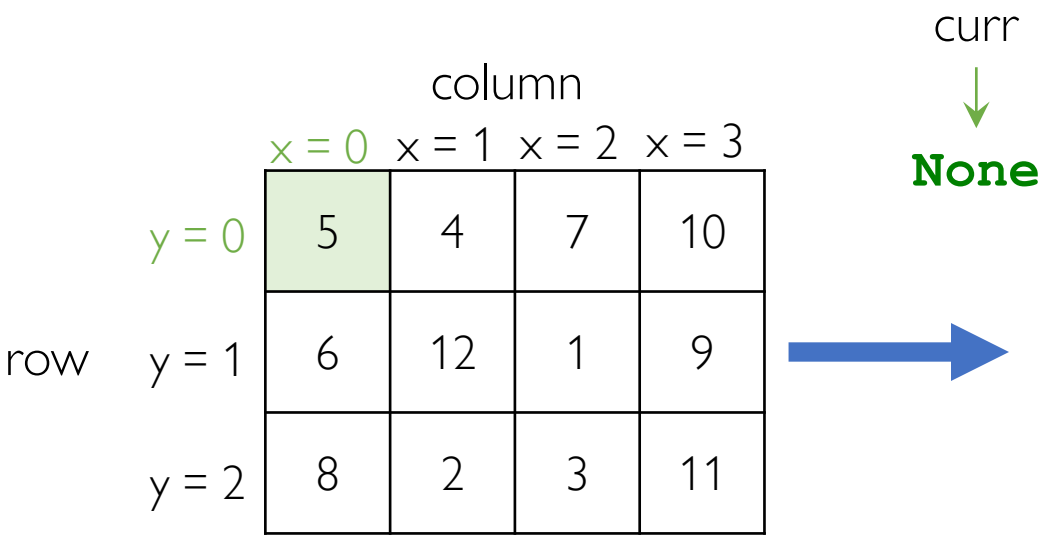
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, y=0, x=0, curr=None)`



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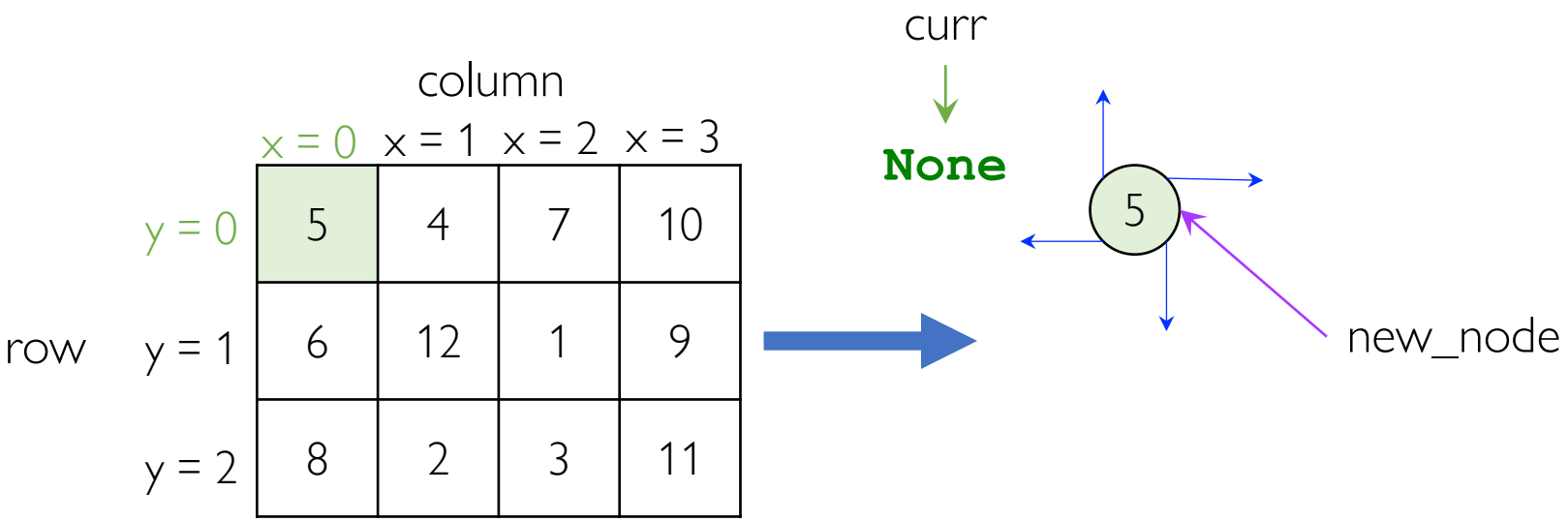


```
new_node = Node(arr[y,x])

... do necessary operations
```

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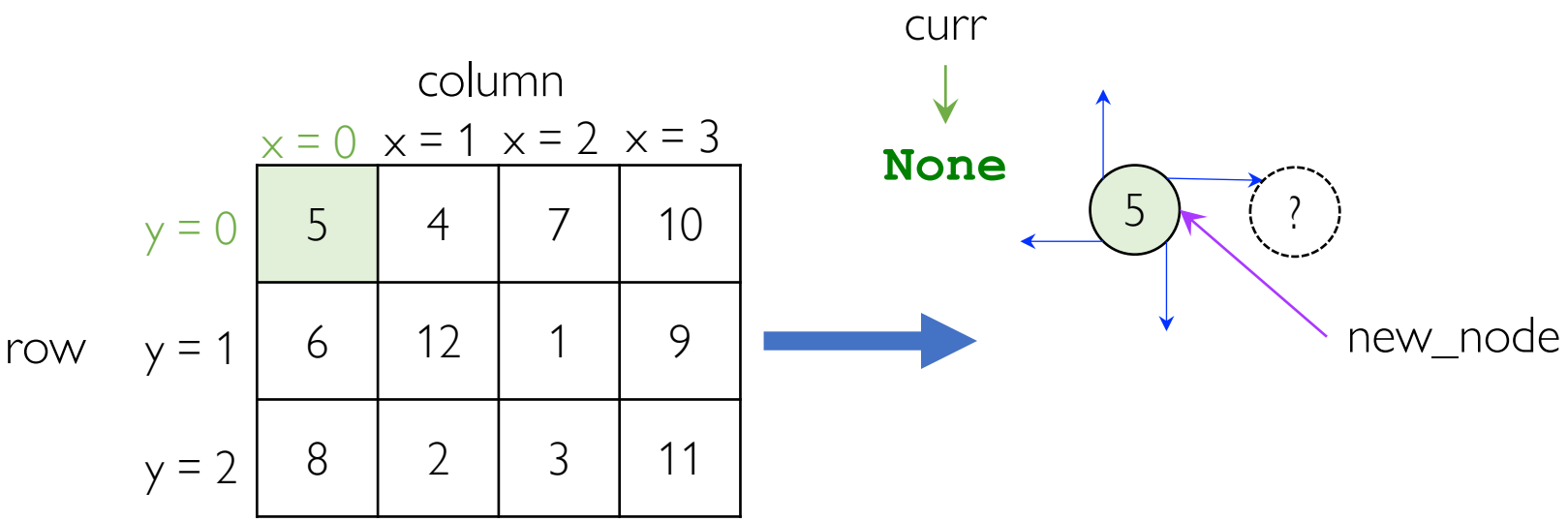


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new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
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constructDLLRecursiveStep

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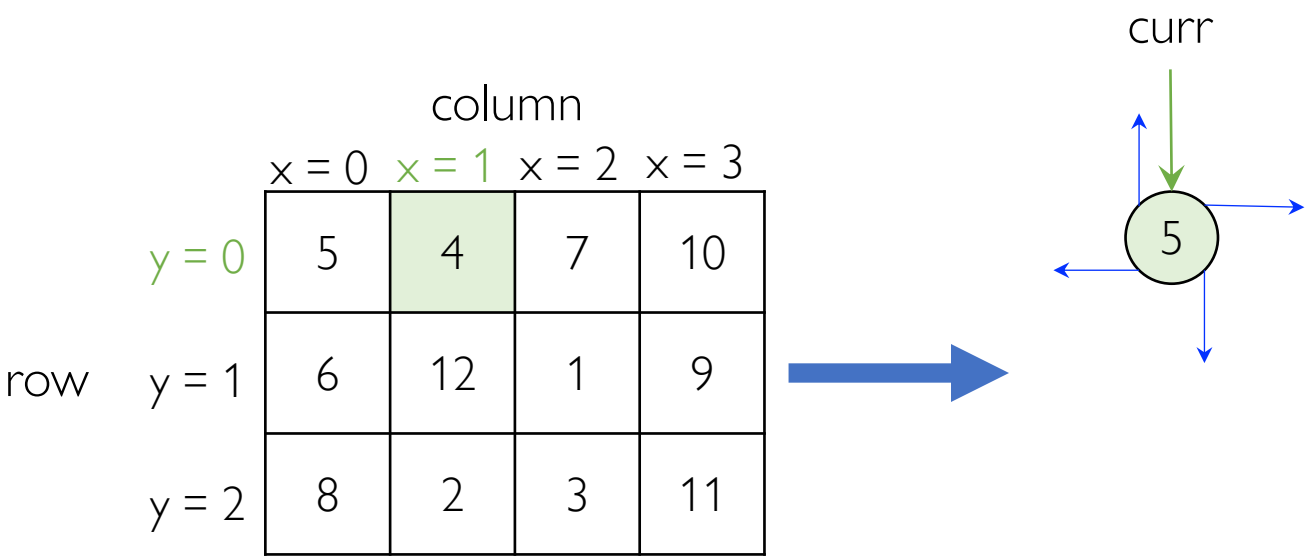

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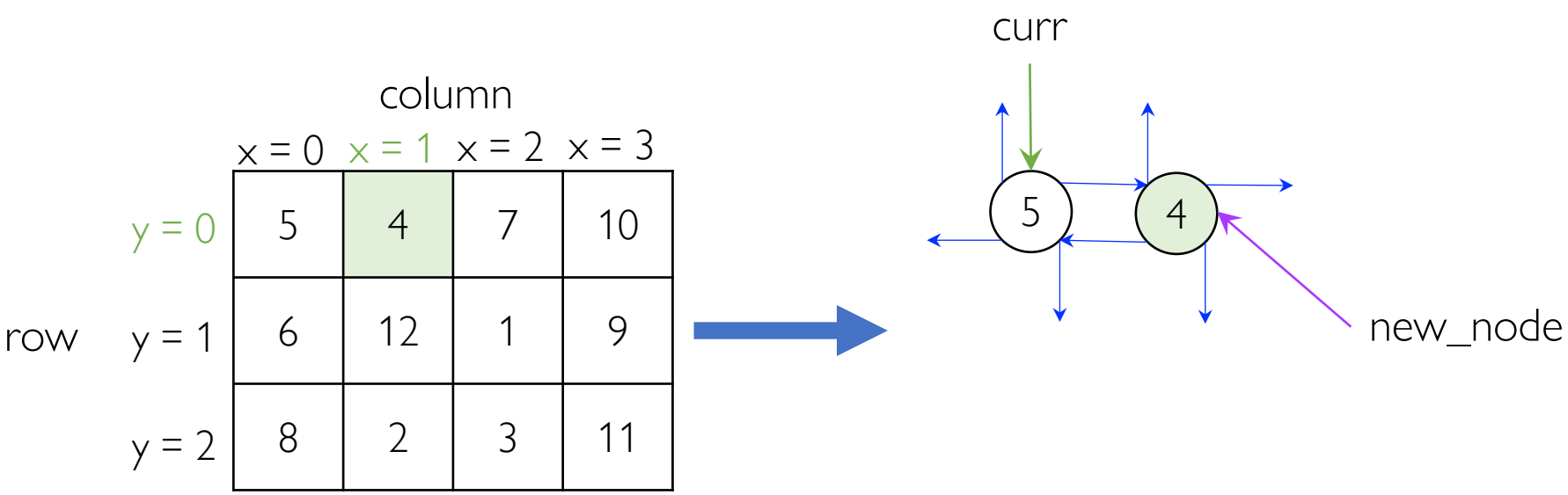


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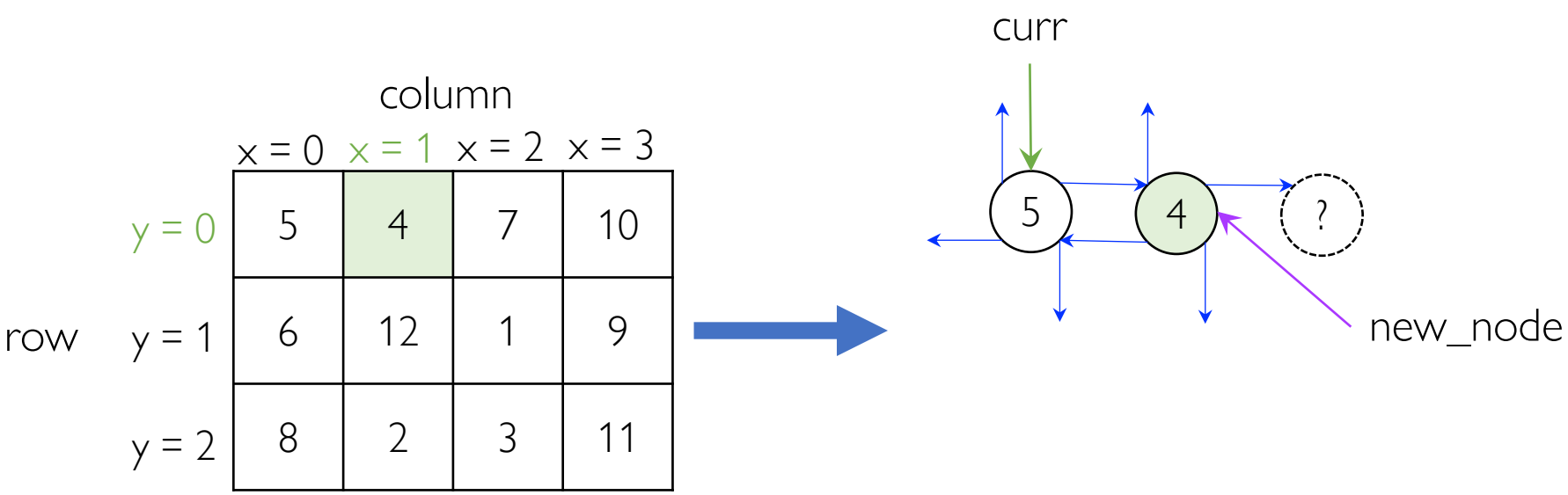


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constructDLLRecursiveStep

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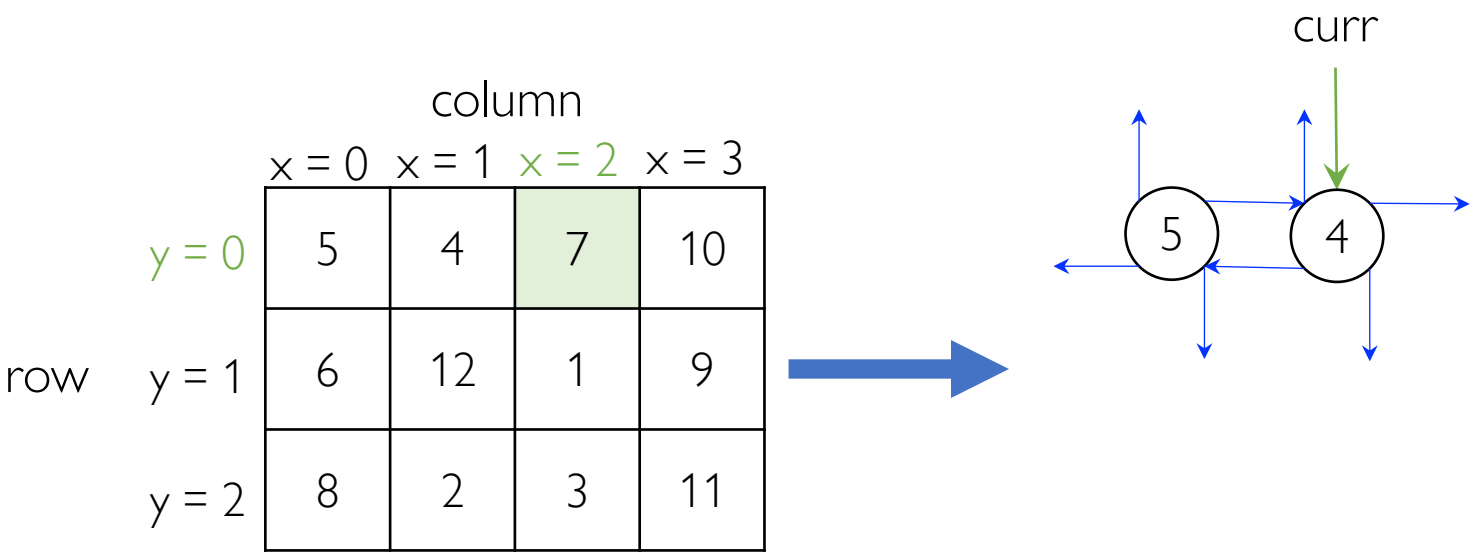

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constructDLLRecursiveStep

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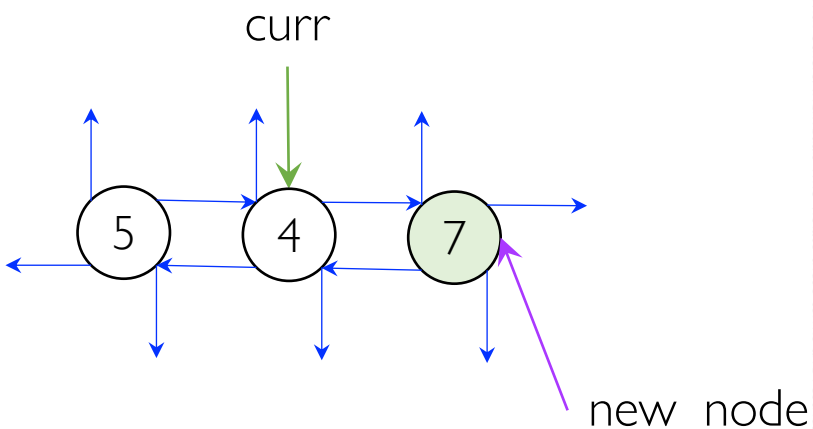


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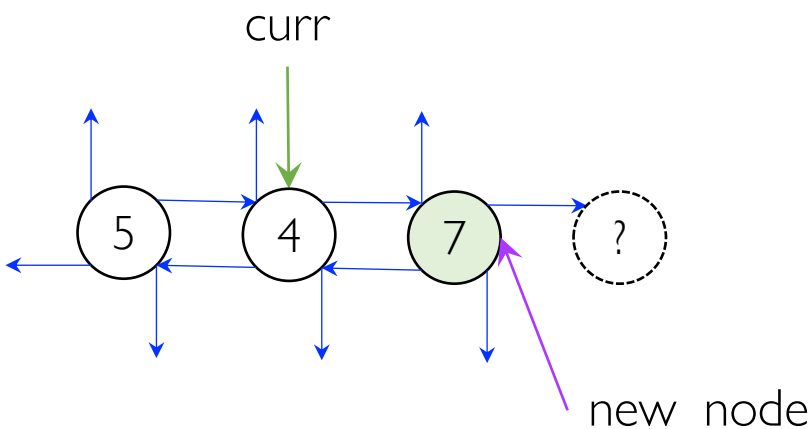


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y = 1	6	12	1	9
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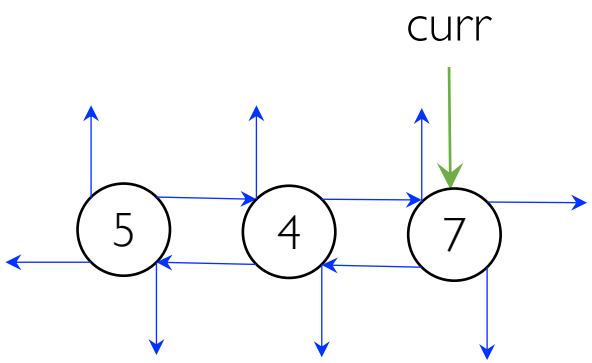

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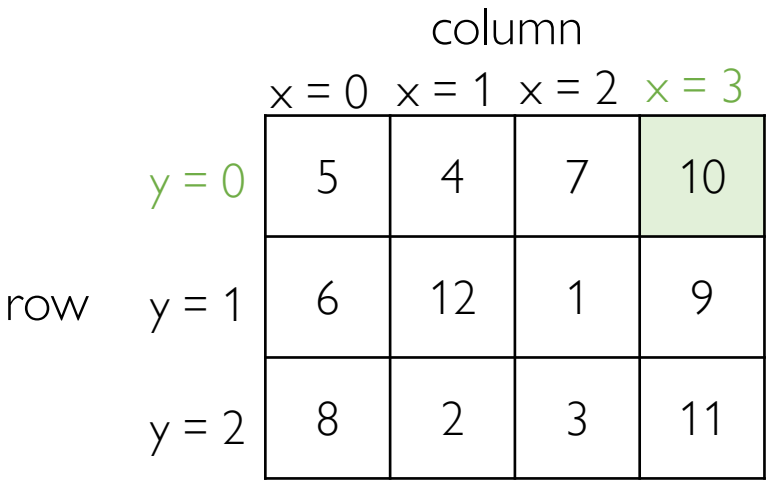
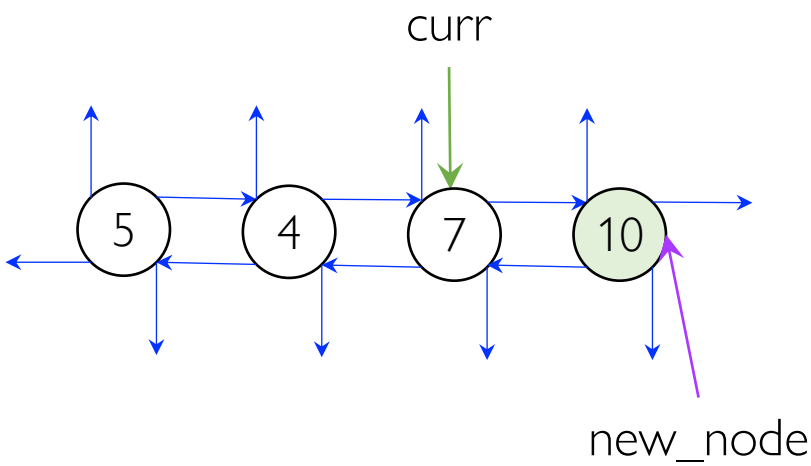
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 3, curr)`






```
new_node = Node(arr[y,x])

... do necessary operations
```

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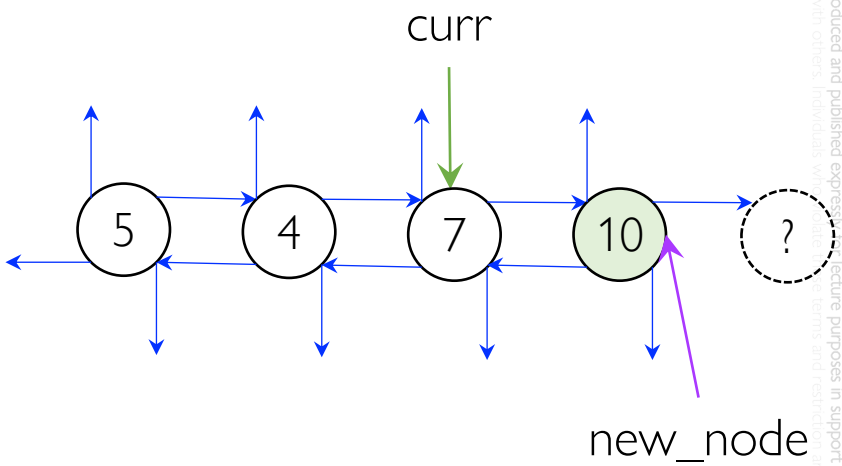
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 3, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

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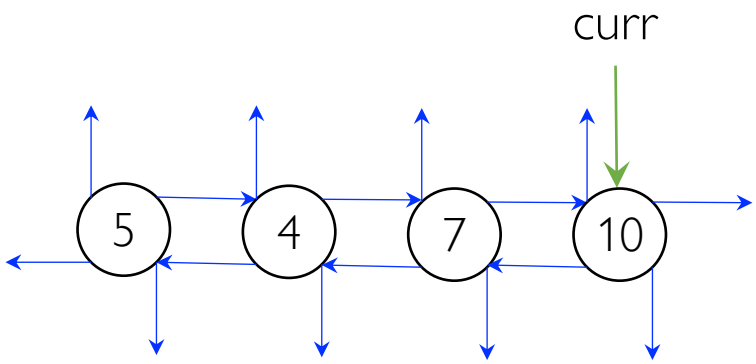
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 4, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
Base case check: x >= width
    return None
```

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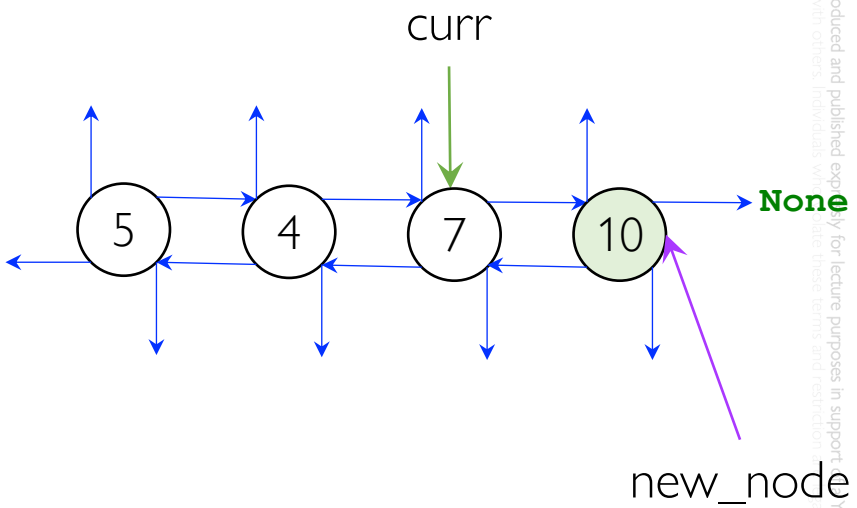
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 3, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

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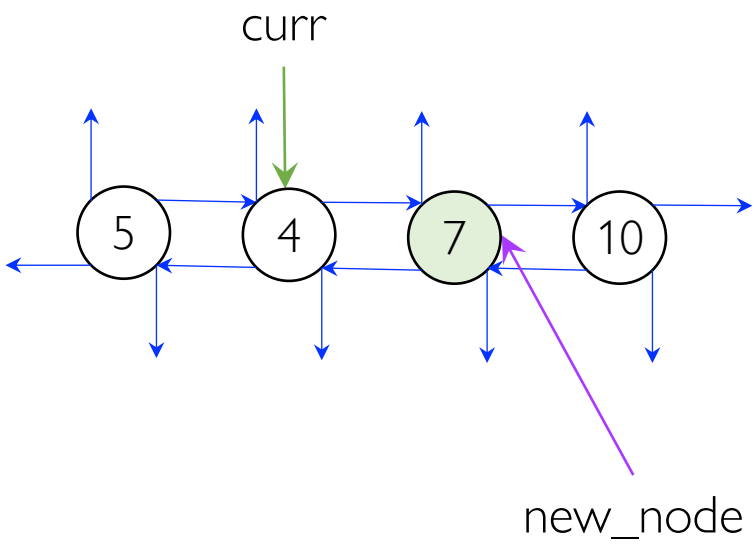
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 2, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

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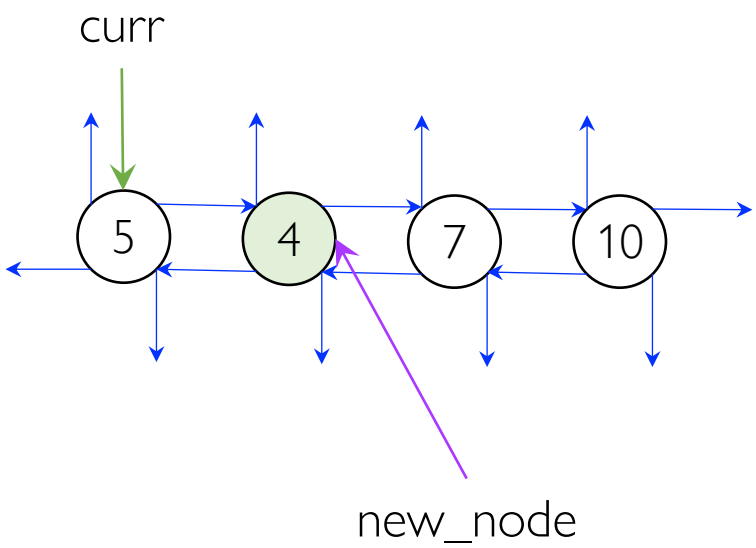
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 1, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

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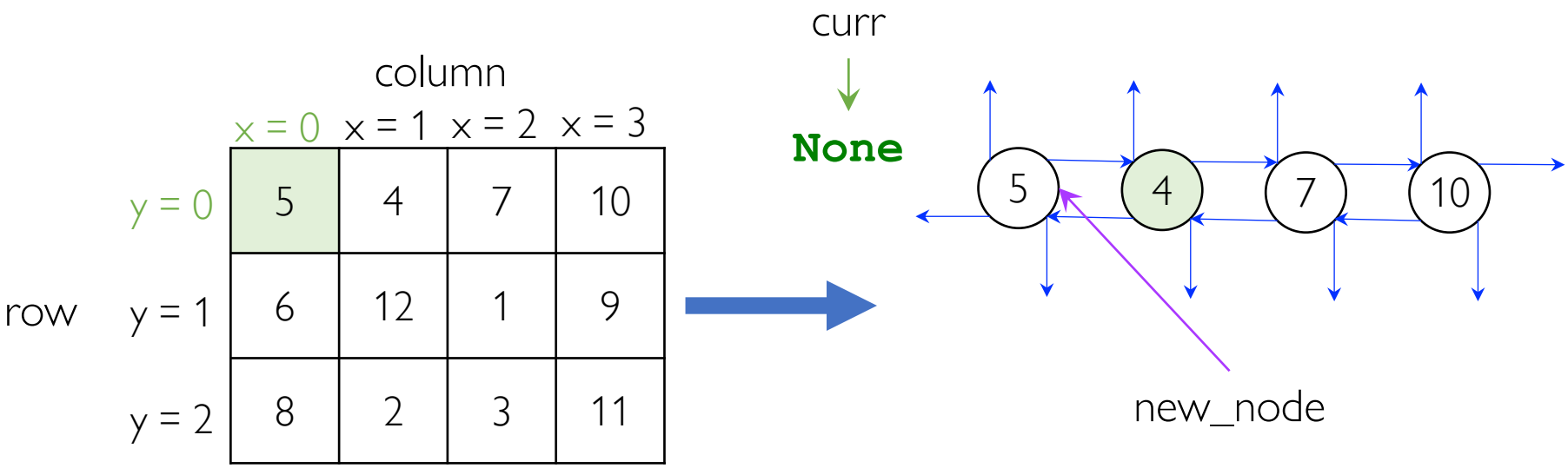
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 0, curr)`




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.down = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

notice this is down instead of right

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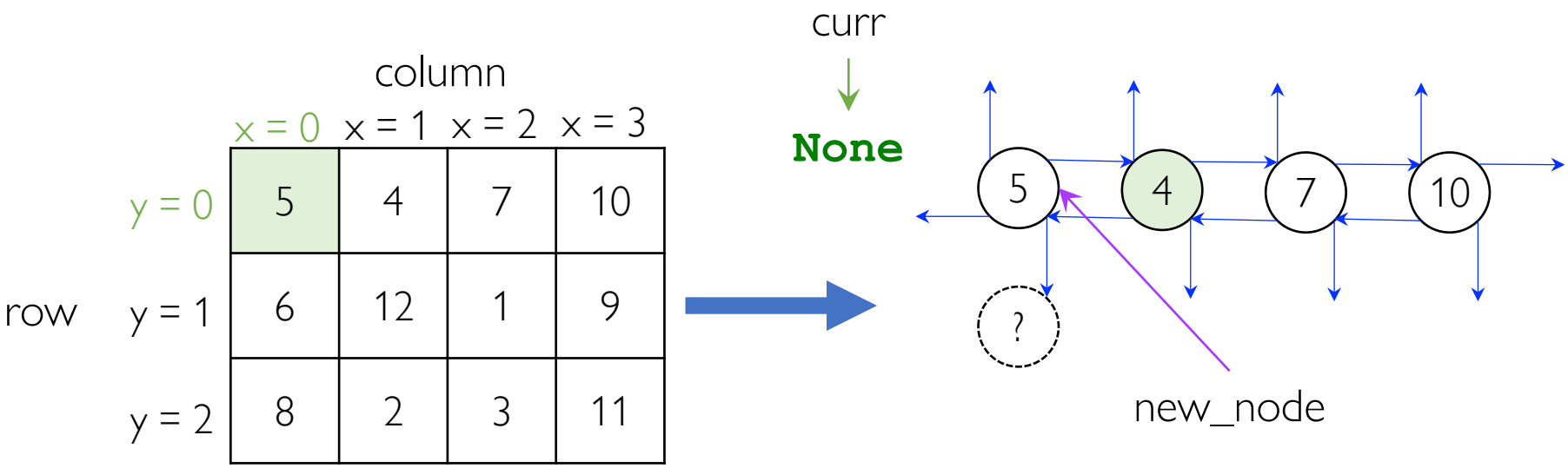
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 0, 0, curr)`




```
new_node.right = constructDLLRecursiveStep(arr, y+1, x, new_node)
```

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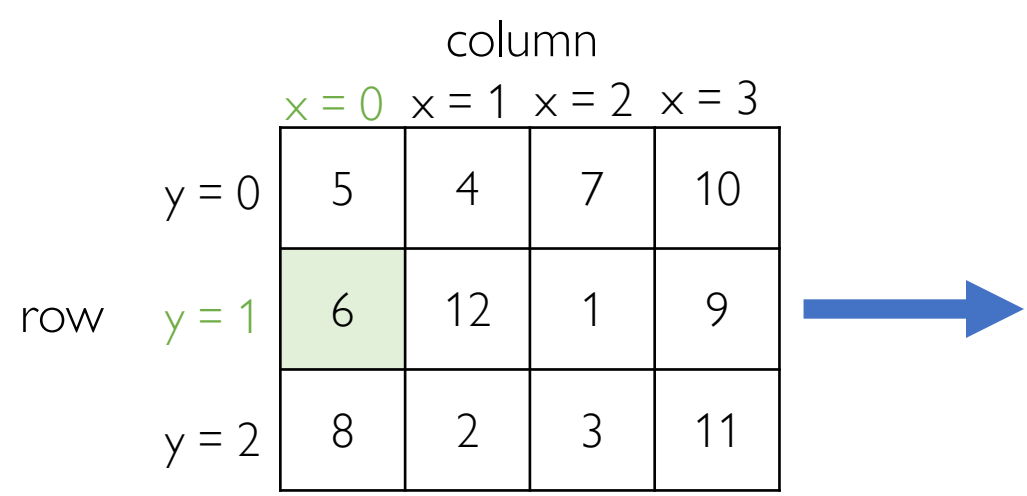
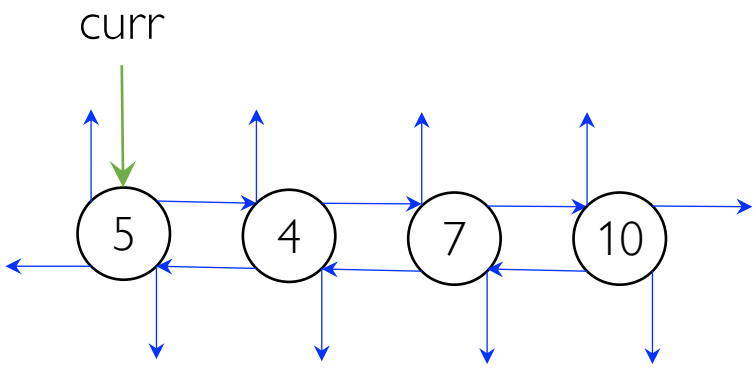
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 1, 0, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11





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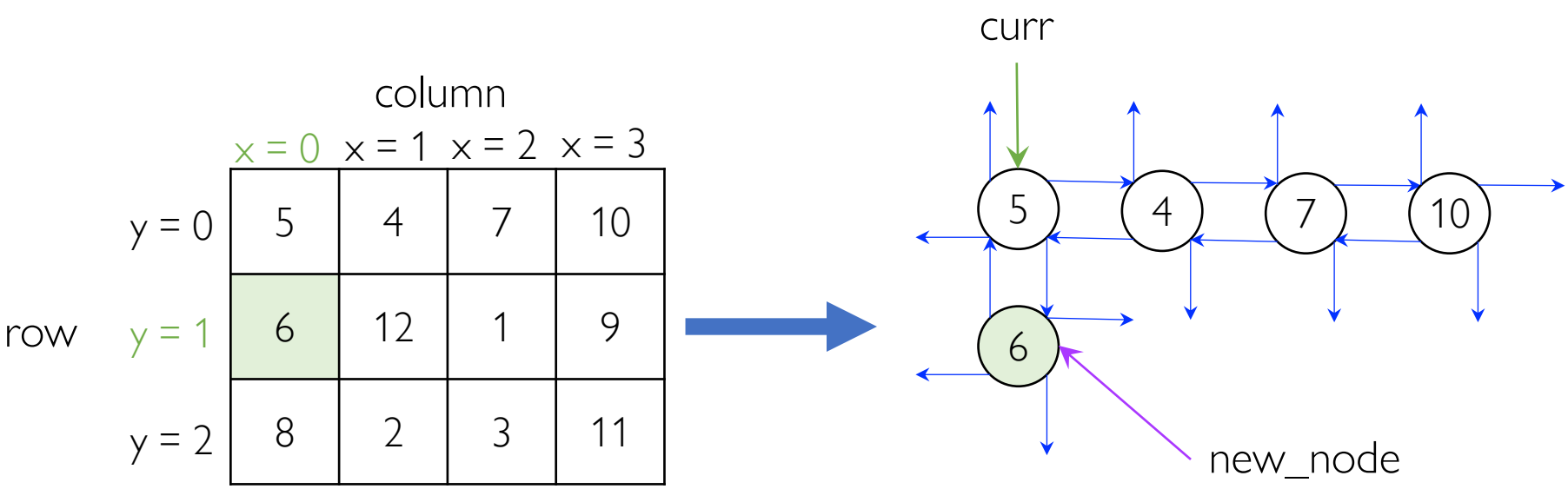
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 1, 0, curr)`




```
new_node = Node(arr[y,x])

... do necessary operations
```

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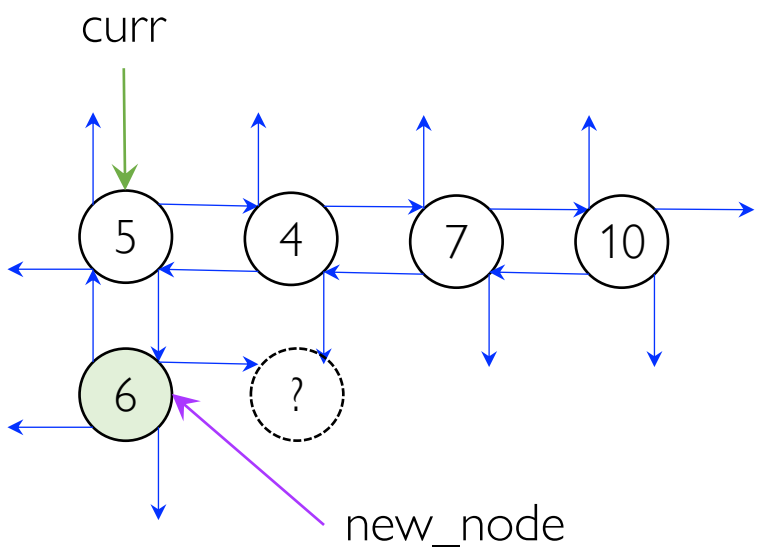
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 1, 0, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations

new_node.right = constructDLLRecursiveStep(arr, y, x+1, new_node)
```

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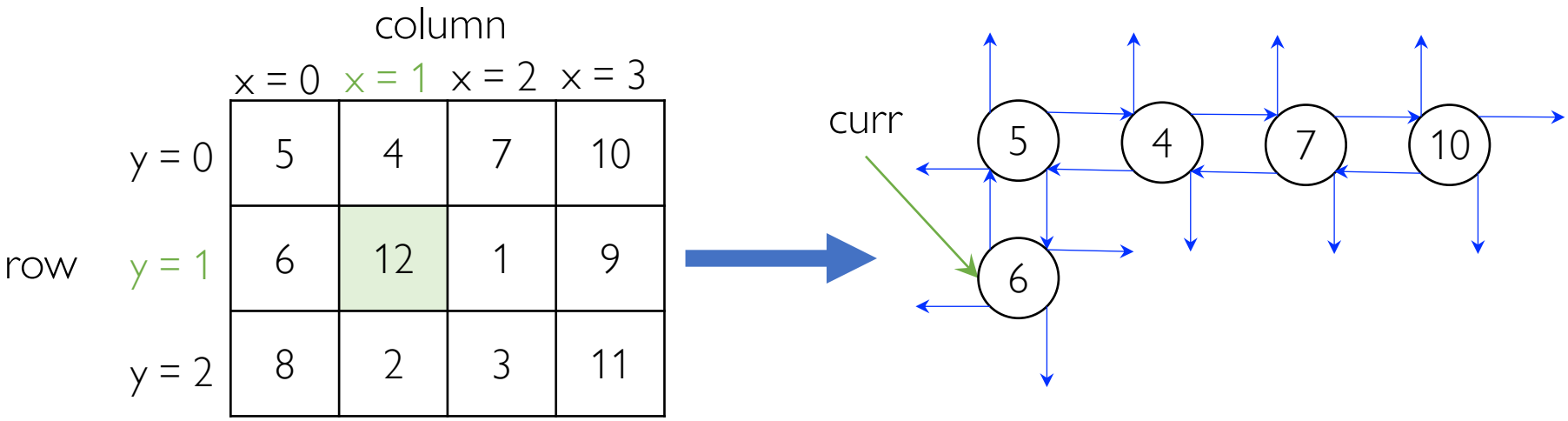
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 1, 1, curr)`



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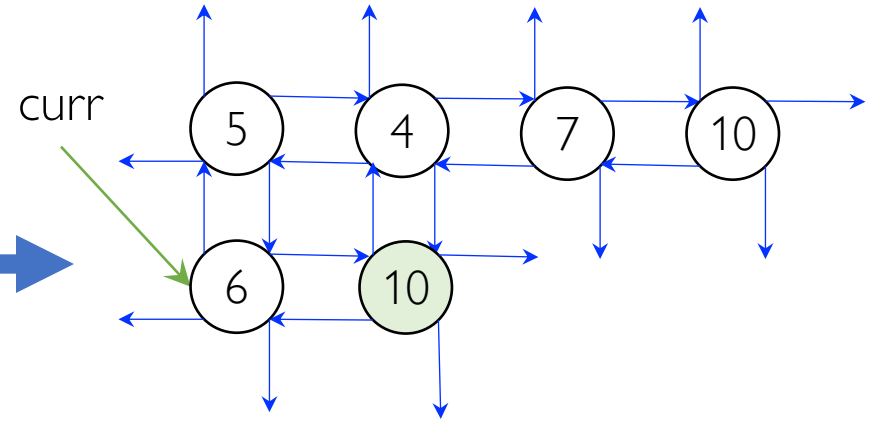
constructDLLRecursiveStep

- `constructDLLRecursiveStep(arr, 1, 1, curr)`

column

row	x = 0	x = 1	x = 2	x = 3
y = 0	5	4	7	10
y = 1	6	12	1	9
y = 2	8	2	3	11




```
new_node = Node(arr[y,x])

... do necessary operations
```

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Part 2: Context-Aware Image Resizing

Context-aware resizing: Removes the "seam" which is the horizontal red path of "uninterestingness". This shrinks the image without "squashing" the objects, keeping their original ratios.

Normal resizing: "squashes" the entire image along with the objects, changing their original ratios.

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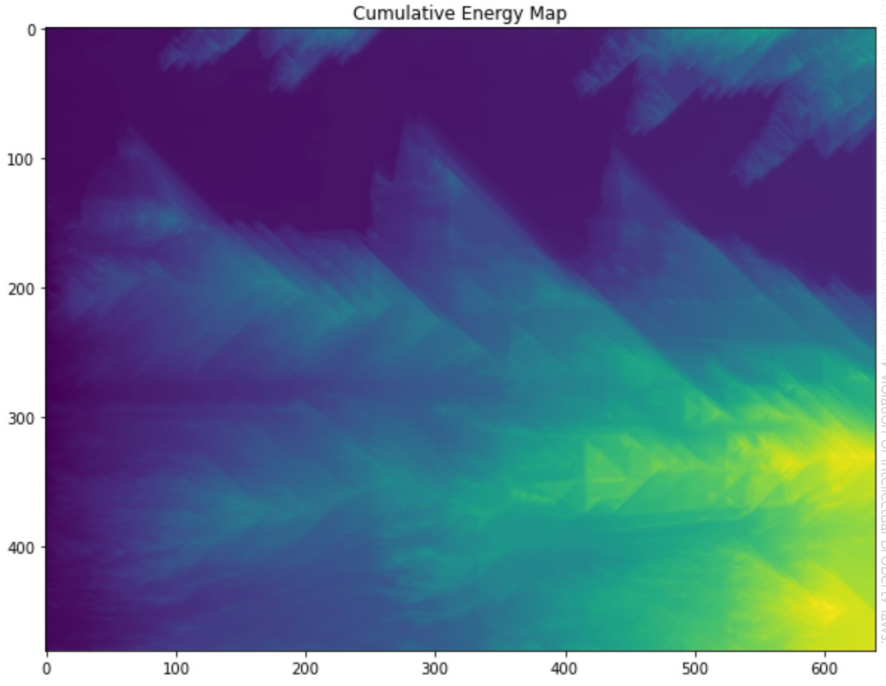
Step 1: Load Image and Compute Energy Map

- Load the image as a 2D array
- Compute its cumulative "energy map" (also 2D array) which computes the level of "interestingness" needed from left edge to right edge
  - Already implemented for you



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Step 1: Load Image and Compute Energy Map

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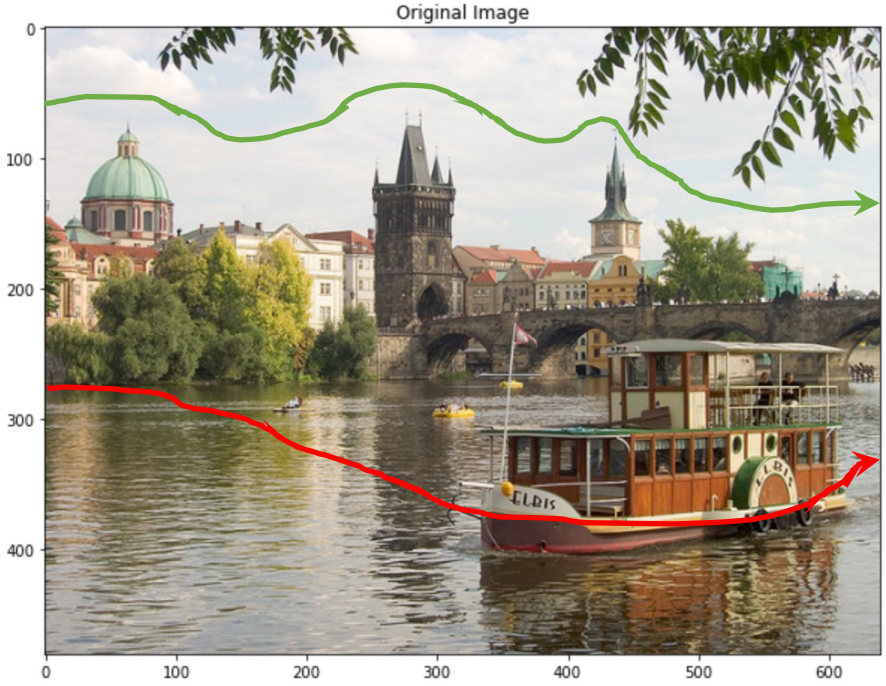
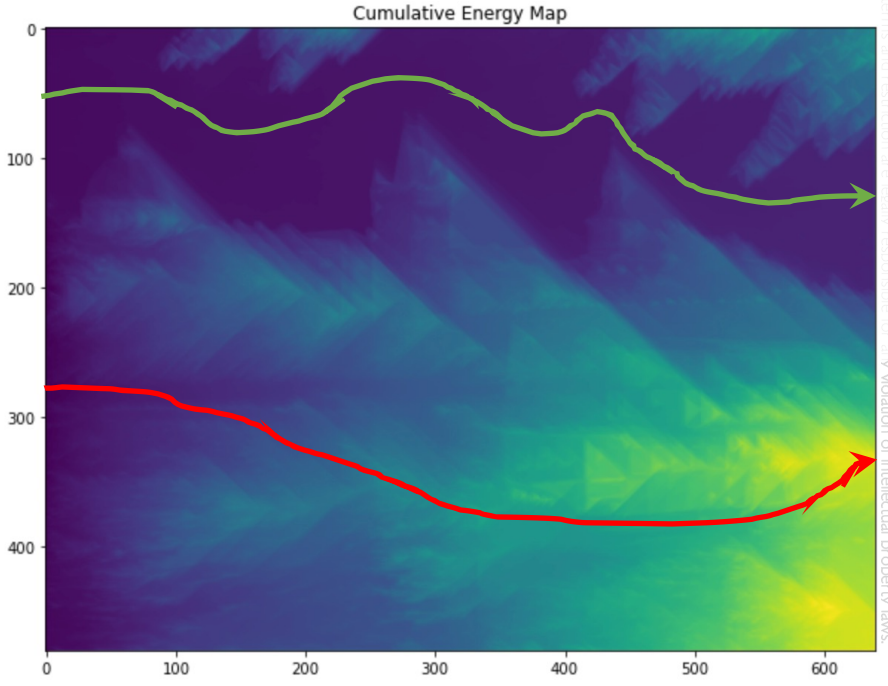
  - Already implemented for you





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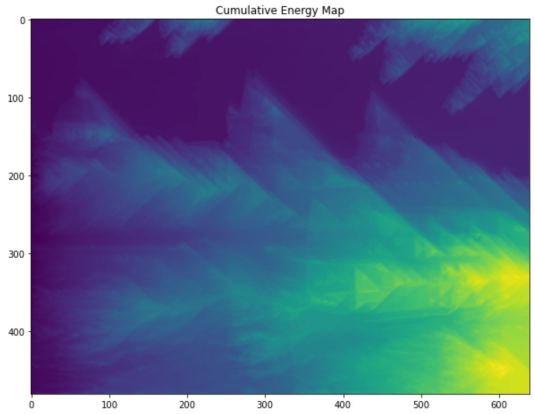
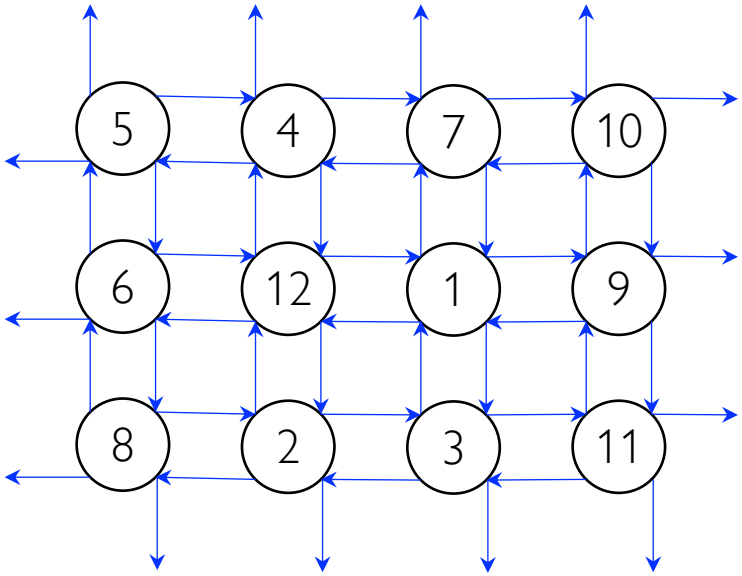
Step 2: Convert 2D arrays to 2D DLLs

- Convert both 2D arrays into 2D DLL using constructDoublyLinkedListLoop function from Part 1.
  - If you completed constructDoublyLinkedListLoop from Part 1, this is also implemented for you



5	4	7	10
6	12	1	9
8	2	3	11



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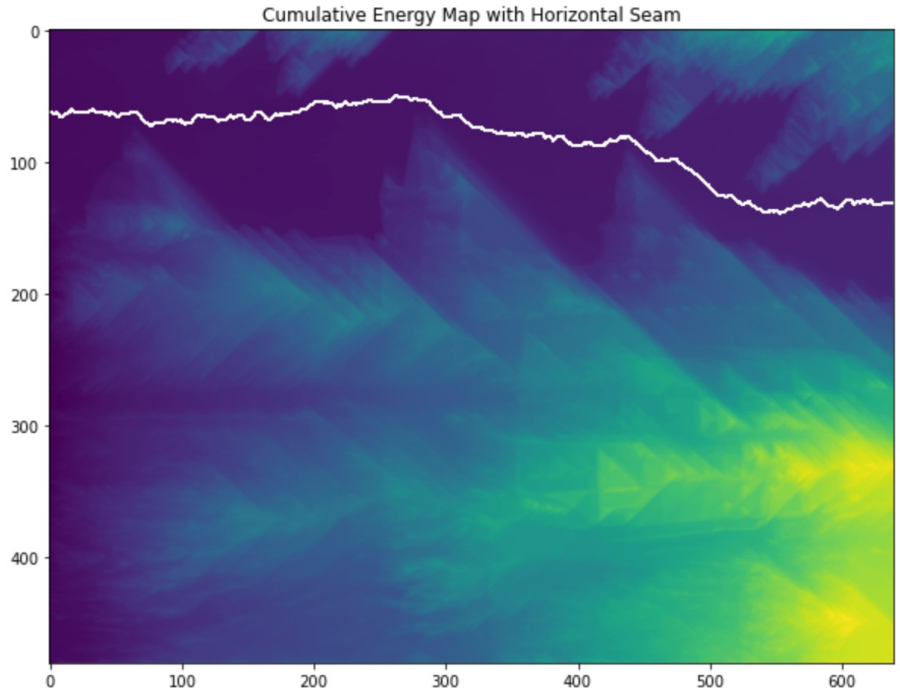
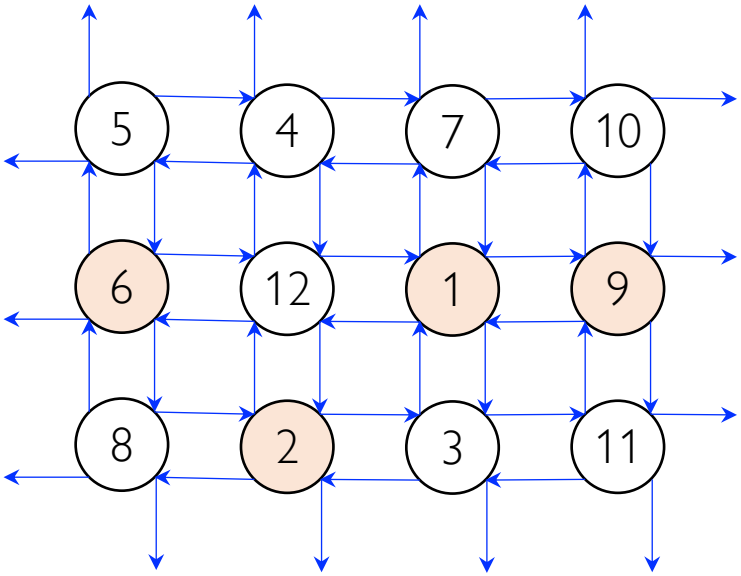
Step 3: Find the "seam" of uninteresting path



- In the energy_map, find the horizontal path called the "seam" using findSeam function
  - Also implemented for you

5	4	7	10
6	12	1	9
8	2	3	11



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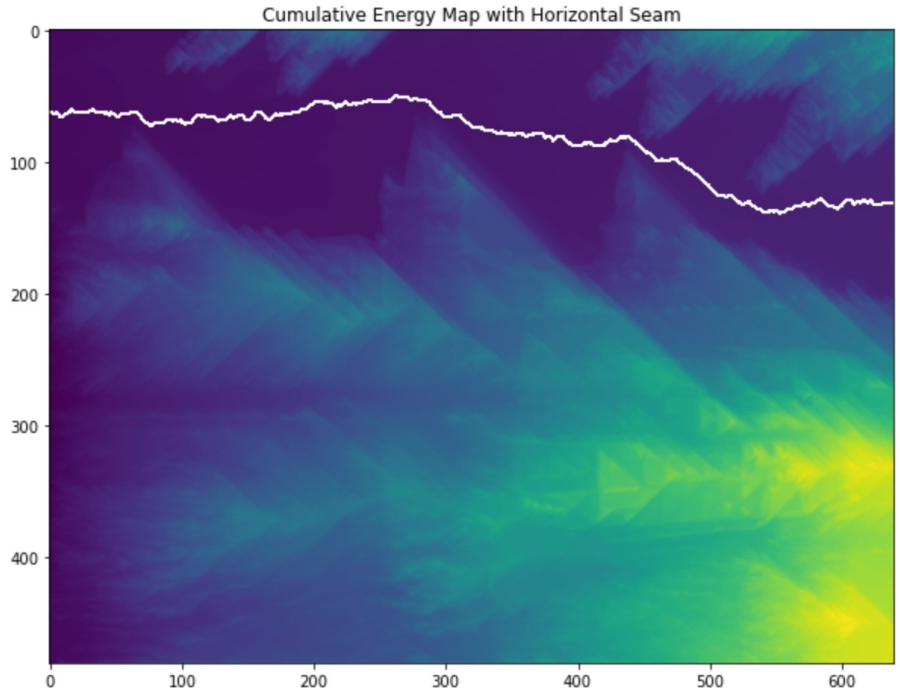
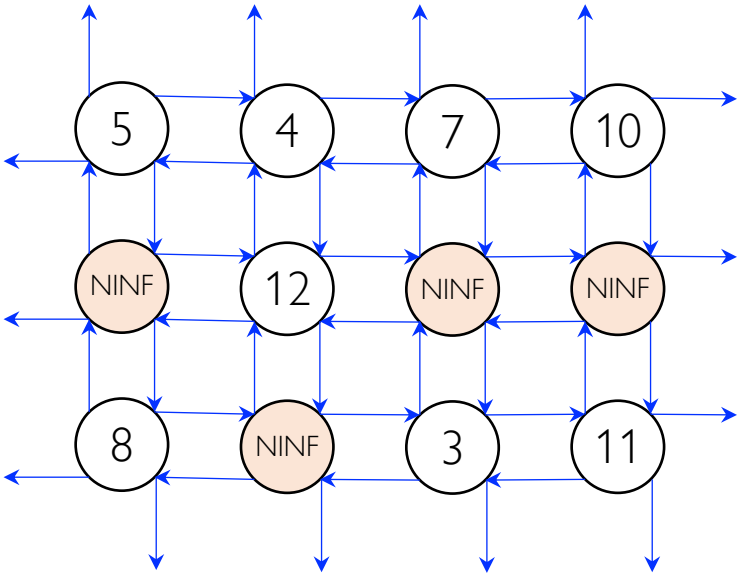
Step 3: Find the "seam" of uninteresting path



- In the energy_map, find the horizontal path called the "seam" using findSeam function
  - Also implemented for you
- The output changes the node values to –infinity (NINF) to "mark" the path

5	4	7	10
6	12	1	9
8	2	3	11



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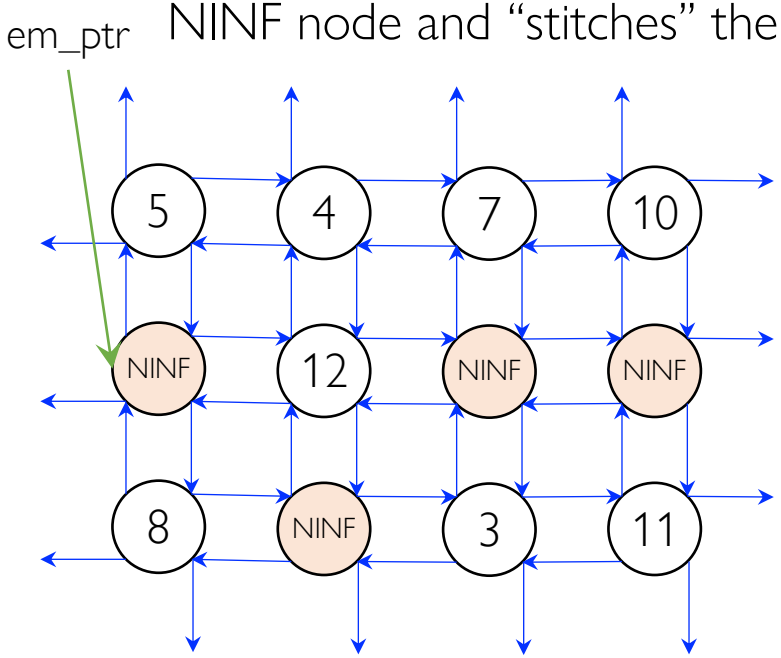
Step 4: Remove the nodes belong to the seam

- Call "removeSeam" function to remove –infinity (NINF) value nodes that represent that seam.
- This calls "removeNodeRecursive" function which recursively removes the NINF node and "stitches" the nearby nodes



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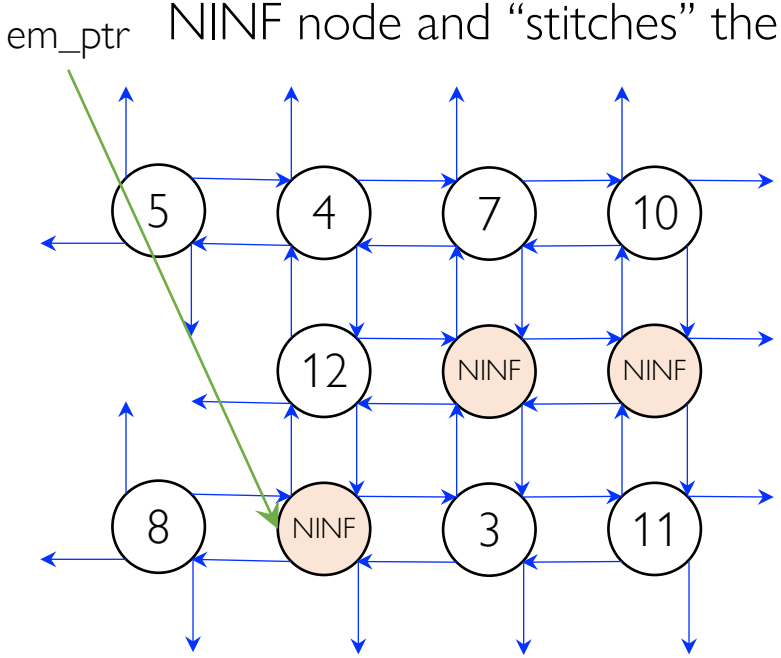

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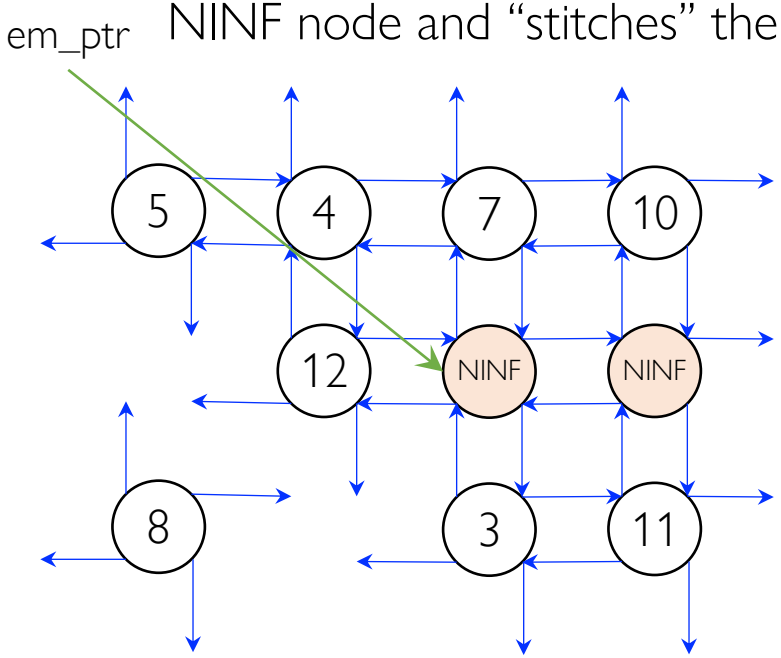

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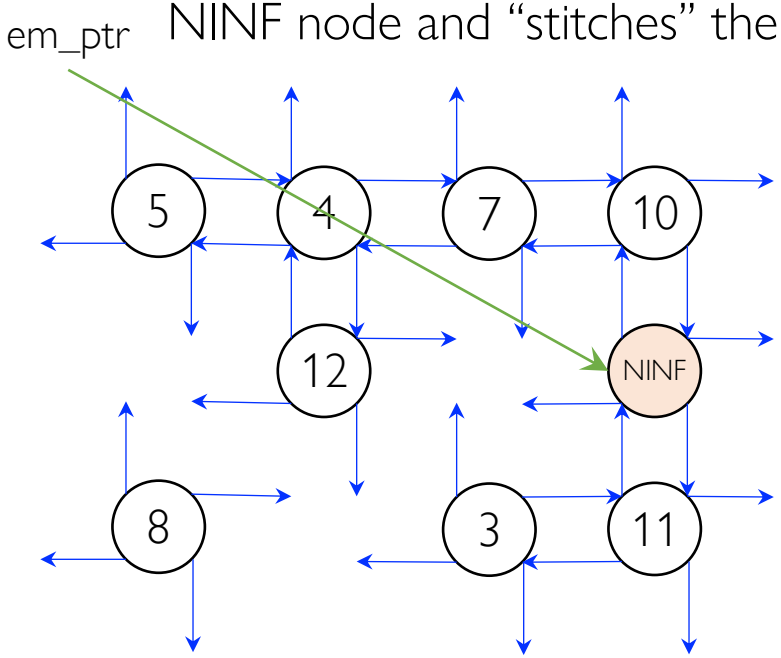

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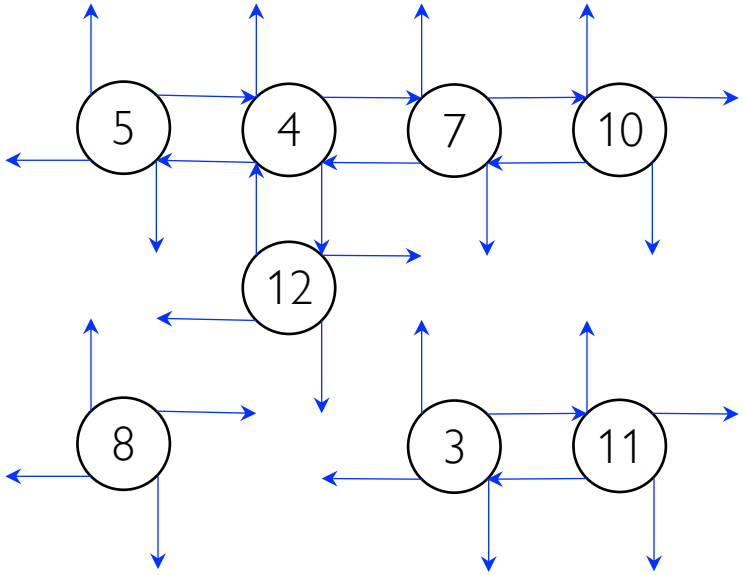
- Call "removeSeam" function to remove –infinity (NINF) value nodes that represent that seam.
- This calls "removeNodeRecursive" function which recursively removes the NINF node and "stitches" the nearby nodes



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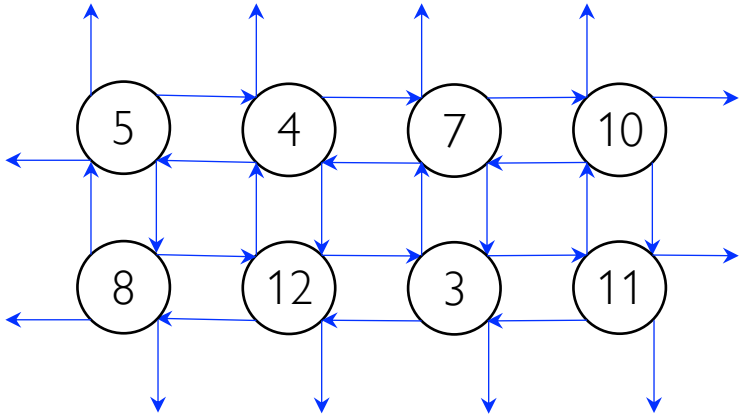
Step 4: Remove the nodes belong to the seam

- Call “removeSeam” function to remove –infinity (NINF) value nodes that represent that seam.
- This calls “removeNodeRecursive” function which recursively removes the NINF node and “stitches” the nearby nodes



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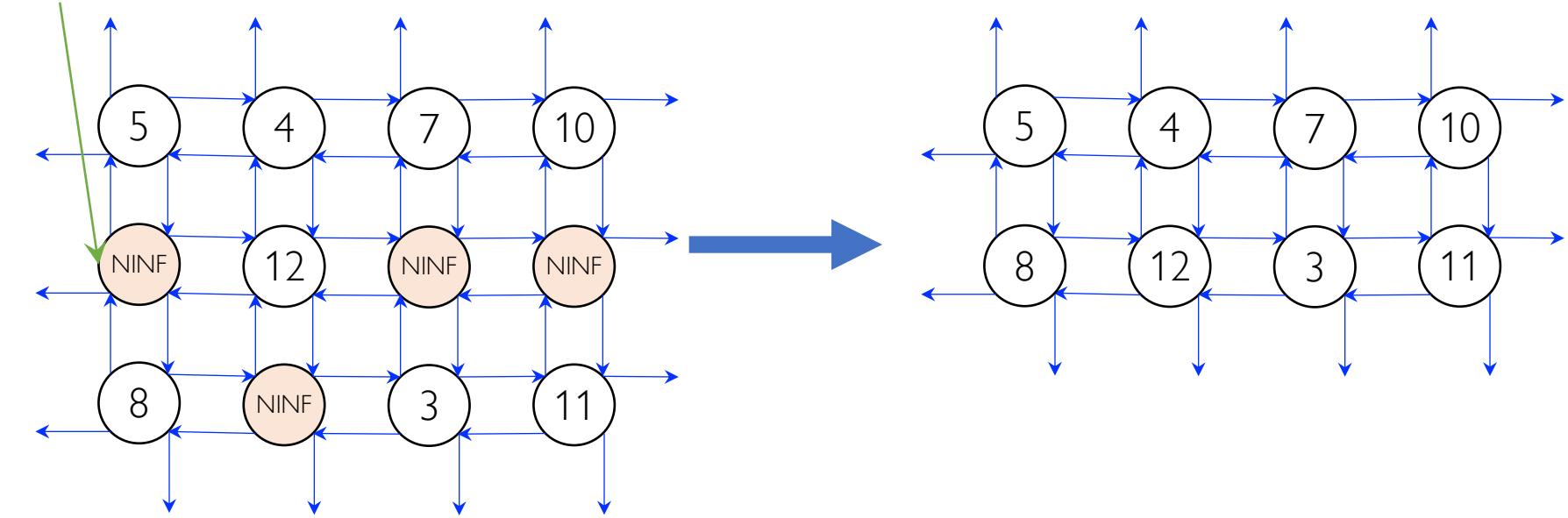

Note: For convenience, you can assume that all NINF nodes have node.up and node.down. The energy map on the provided image will not compute paths along the top and bottom edges of the image.

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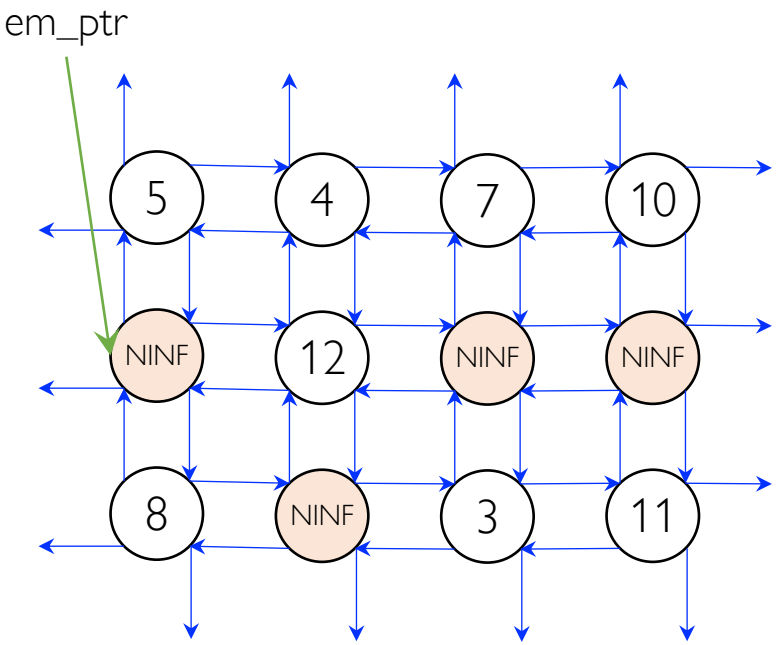
Step 4: Remove the nodes belong to the seam

- Note that this removal based on energy map should also happen to image
  - recall, we use the energy map to identify the seam to ultimately remove the seam of the image



energy map
(2D DLL)

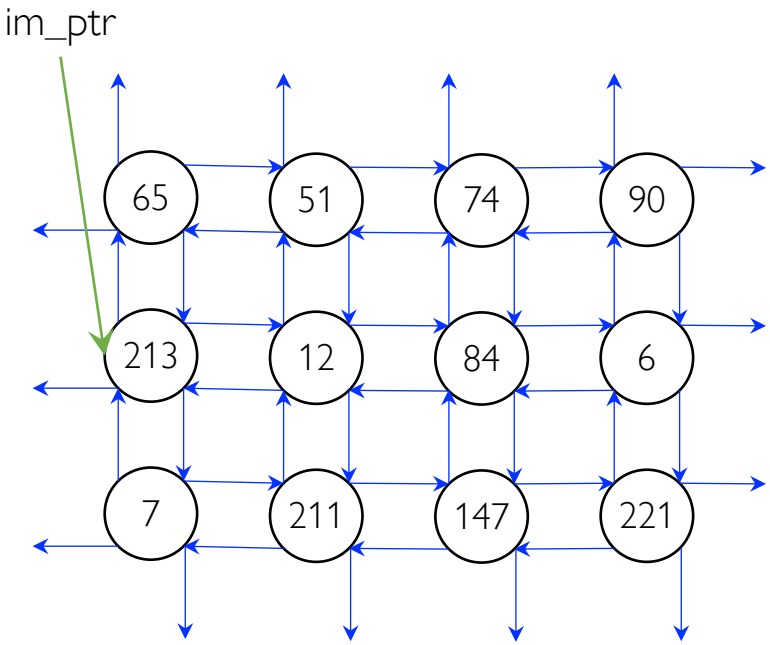


image
(2D DLL)

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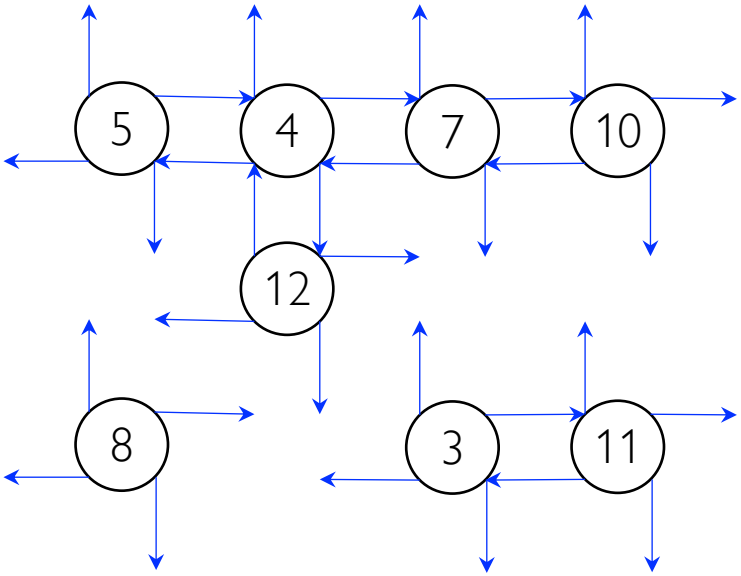
Step 4: Remove the nodes belong to the seam

- Note that this removal based on energy map should also happen to image
  - recall, we use the energy map to identify the seam to ultimately remove the seam of the image
- One call to removeSeam reduces image by 1 pixel



energy map
(2D DLL)

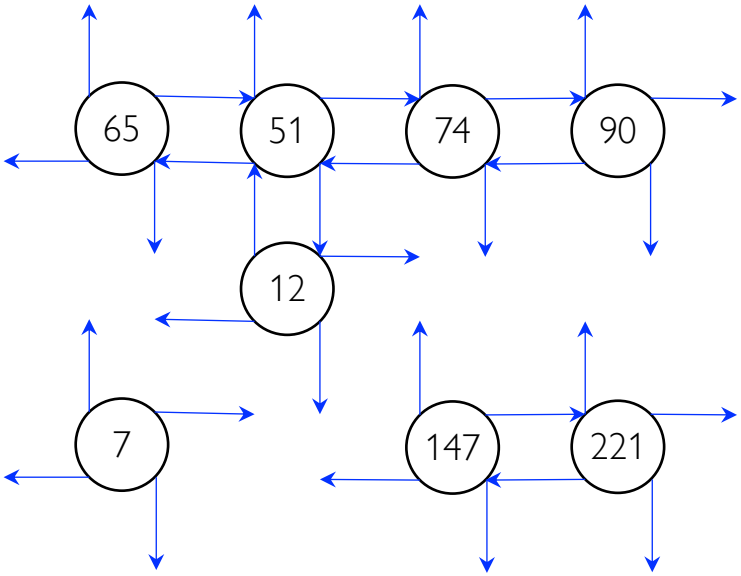


image
(2D DLL)

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Step 4: Remove the nodes belong to the seam

- We repeatedly findSeam and removeSeam to reduce the image by 1 pixel at a time
- Once removed, turn 2D DLLs into 2D arrays for plotting

Original image

Repeatedly removing the seam

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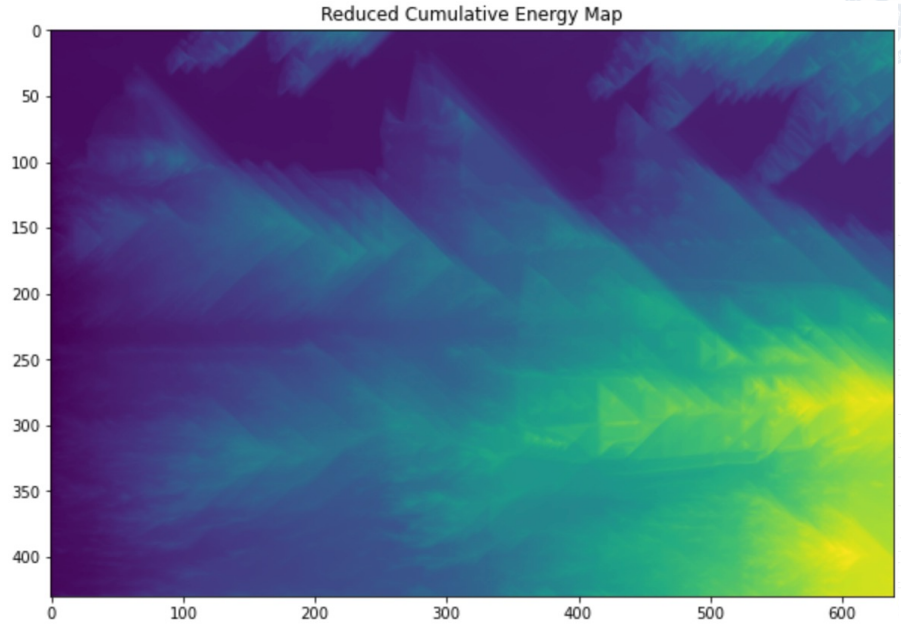
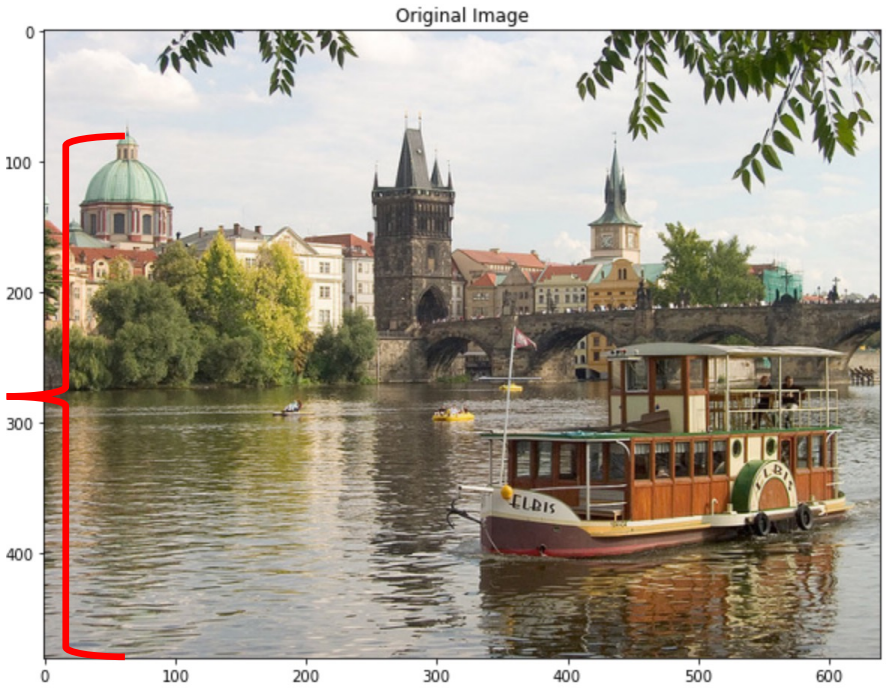
Step 4

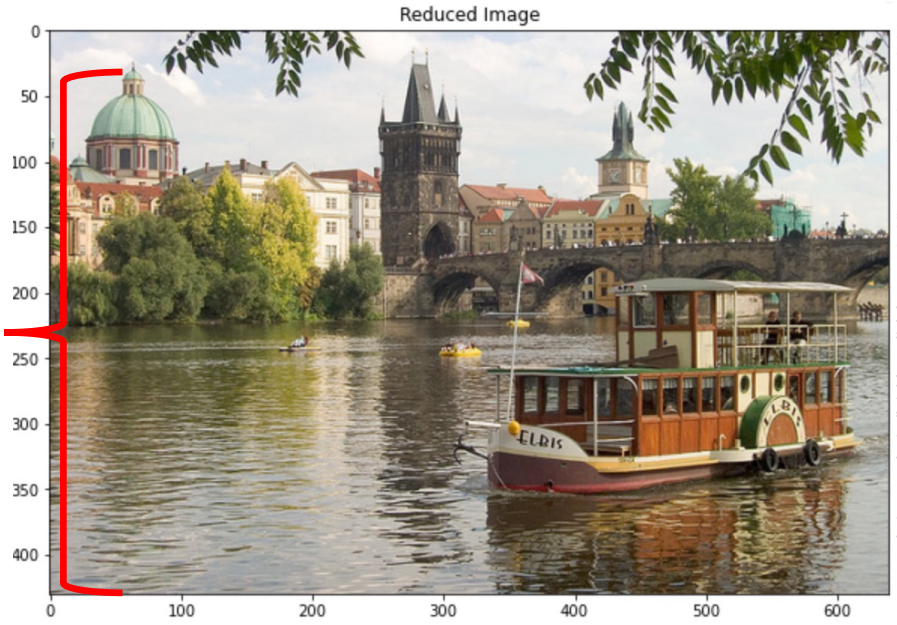
- We repeatedly findSeam and removeSeam to reduce the image by 1 pixel at a time
- Once removed, turn 2D DLLs into 2D arrays for plotting
  - Step 5 implemented



Reduce energy map



Original image



Reduce image

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Summary

- Walk through **assignment2.ipynb**
- Implement missing functions in **doublylinkedlist.py**
- Don't modify **vision_utils.py**
- Part 1:
  - constructDoublyLinkedListLoop
  - constructDoublyLinkedListRecursiveStep
- Part 2:
  - getWidth
  - removeNodeRecursive

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