CS 261-020
Data Structures

Lecture 3

C Basics

Dynamic Array vs. Linked List

1/23/24, Tuesday

Odds and Ends

- All office hours posted – at KEC 1130

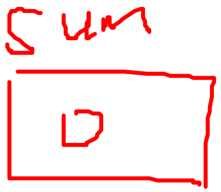
- Recitation 2: instead of +3, you are allowed to make up for full credits by the beginning of your next week's recitation time

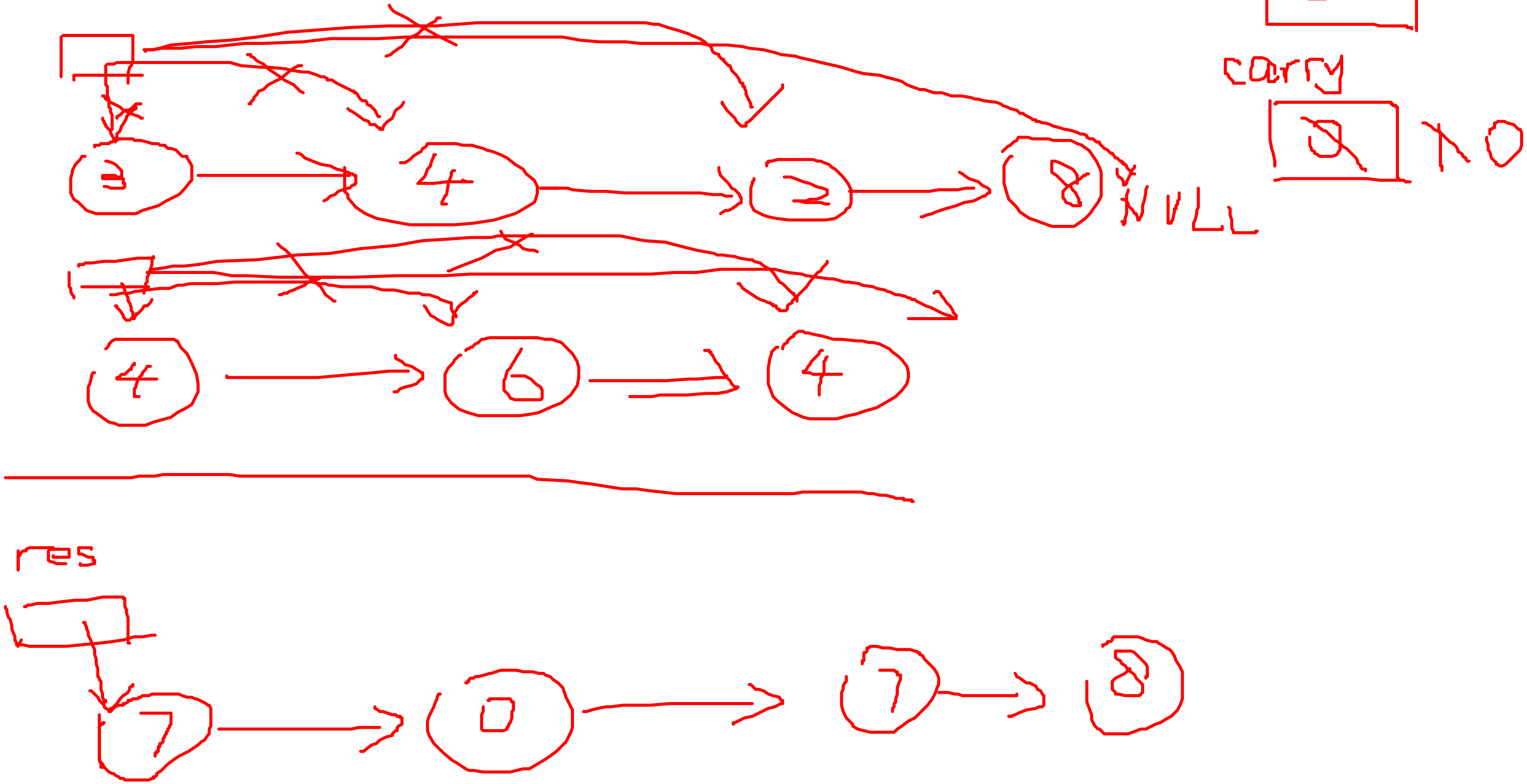
- Recitation 3 posted
  - You will have more time working on recitation 2 ☺

Odds and Ends

- Sign up for Demos:
  - Where? – TA Hours page on Canvas
  - Assignment 1
    - Code due: Sunday (Jan 28)
    - demo due: Friday of week 5 (Feb 9)
  - For those who already signed up for demos this week, you are allowed to reschedule or demo the assignment right away.
    - No 2nd demo after the due date, i.e., only one demo allowed per assignment

Hints for recitation 2





Lecture Topics:

- C Basics
  - Function pointer
- Dynamic Array
- Linked List

Recap: C Basics – Void Pointers (void*)

- A void pointer is a pointer represented by the type `void*`.
- A void pointer is a generic pointer, it can point to data of any data type.
  - E.g., a void pointer points to an integer

```
int var = 20;
void *v_ptr = &var;
```

- Why `void*`?
  - It allows the data structures to contain data of any type while remaining type agnostic

C Basics – strings in C (cont.)

- The null character is important → indicates the end of the string
- Functions rely on ‘`\0`’:
  - `printf()` – know when to stop processing the string
  - `strlen()` – returns the number of characters in a string
    - Count until it finds a null character

- Allocating memory to store a string: num of char + null char
  - Q: How many char can we store in the `str`?

```
char* str = malloc(64 * sizeof(char));
```

63

+1 for '\0'

C Basics – strings in C (cont.)

- Constant strings in C:

```
char* name = "Harry Potter";
```

char name[64]

- Constant strings are read-only, thus cannot be modified.

```
name[0] = 'l'; //illegal but no error message
```

- Best to mark it be constant

```
const char* name = "Harry Potter";
name[0] = 'l'; //illegal with compiling error
```

C Basics – strings in C (cont.)

- Useful functions for C strings: → #include <string.h>
  - strlen() – returns the number of characters in the string
  - strncpy() – copy a specified number of characters from one string to another
  - snprintf() – “printing” content into a string, up to a specified number of characters
    - From <stdio.h>
  - strcmp() – compare two strings, returns 0 if they are equal

    if(strcmp(str1, str2)==0)
  - And many more… check string.h

C Basics – Function pointers

- Function pointers allows us to store the memory address of a function in a variable and use that memory address to call the function being pointed to
  - Allows us to pass functions as arguments to other functions

- Why would we want to pass a function as an argument to another function?

- Consider this…

C Basics – Function pointers

- Write a function to sort an array
- To make it work for any type,
  - each element is void*, and thus the pointer to the array is void**

```
void sort(void** arr, int n); //can pass arr of any type into this function
```

- Question: How does sort() be able to compare the values in the array?
  - Use function pointers!
  - The function *calling* our sort() and passing data into it does know these things

C Basics – Function pointers

- Add a function pointer:
  - A function that compares two values from the array to be sorted and return a value indicating which is bigger/smaller
  - `int cmp(void* a, void* b);`

  - So our sort() becomes to:

```
void sort(void** arr, int n, int (*cmp)(void* a, void* b));
```

C Basics – Function pointers

- To use this function pointer
  - the calling function will need access to a function for *comparing* elements, i.e., integers
  - This function will have to match the prototype of the function pointer argument to our sort()
  - E.g.,

```
int compare_ints(void* a, void* b) {
  int* ai = a, *bi = b;   /* Cast void* back to int*. */
  if (*ai < *bi)
    return 0;
  else
    return 1;
}
```

  - Function call will be:

```
sort((void**)array_of_ints, number_of_ints, compare_ints);
```

C Basics – Function pointers

```
void sort(void** arr, int n, int (*cmp)(void* a, void* b));
```

- Within sort():
  - Whenever we need to compare two values from the array being sorted, we can just call cmp()

```
if (cmp(arr[i], arr[j]) == 0) {
  /* Put arr[i] before arr[j] in the sorted array. */
}
else {
  /* Put arr[i] after arr[j] in the sorted array. */
}
```

- Demo….

Lecture Topics:

- C Basics
- Dynamic Array
- Linked List

Abstract Data Type (ADT)

- Abstract Data Type (ADT) – a mathematical model for data types
- Specifies:
  - the type of data stored
  - the operations supported on them
  - the types of parameters of the operations.
- Why “abstract”?
  - an implementation-independent view of the data type

Dynamic Arrays

- Elements in an array are stored in a contiguous block of memory
- Allow random access (direct access)
  - i.e., time to access the 1st element = time to access the last element
  - By using array subscript ([]):

```
int* array = malloc(1000 * sizeof(int));
array[0] = 0;
array[999] = 0;
```

- Demo…

Dynamic Arrays (cont.)

- Basic operations:
  - get – Gets the value of the element stored at a given index in the array
  - set – Sets/updates the value of the element stored at a given index in the array
  - insert – Inserts a new value into the array at a given index.
    - Sometimes, dynamic array implementations limit insertion to a specific location in the array, e.g. only at the end.
  - remove – Removes an element at a given index from the array
    - Sometimes, dynamic array implementations avoid moving elements up a spot by only allowing the last element to be removed

Dynamic Arrays (cont.)

- Drawbacks:
  - Fixed size, must be specified when the array is created
    - For static array:

```
int array[50];
```

    - For dynamic array:

```
int *array = malloc (50 * sizeof(int));
```

→Need to allocate more memory if we need to store more data
  - How?
- Dynamic array DS doesn't have a fixed capacity
  - Has a variable size and can grow as needed

Dynamic Arrays (cont.)

- Need to keep track of three things:
  - data – underlying data storage array
  - size – number of elements currently stored in the array
  - capacity – number of elements data has space for before it must be resized
- How it works?
  - An array of known capacity is maintained by the dynamic array DS.
  - As elements are inserted, they are simply stored in data
  - If an element is inserted into the dynamic array, and there isn't capacity for it in the underlying data storage array (data), the capacity of the underlying data storage array is doubled. Then the new element is inserted into this larger data storage array.

Dynamic Arrays

5	

5	8

5	8	1	

5	8	1	4

5	8	1	4	9			

5	8	1	4	9	0		

5	8	1	4	9	0	6	

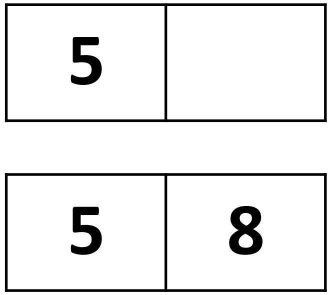
5	8	1	4	9	0	6	7

5	8	4	9	0	6	7	

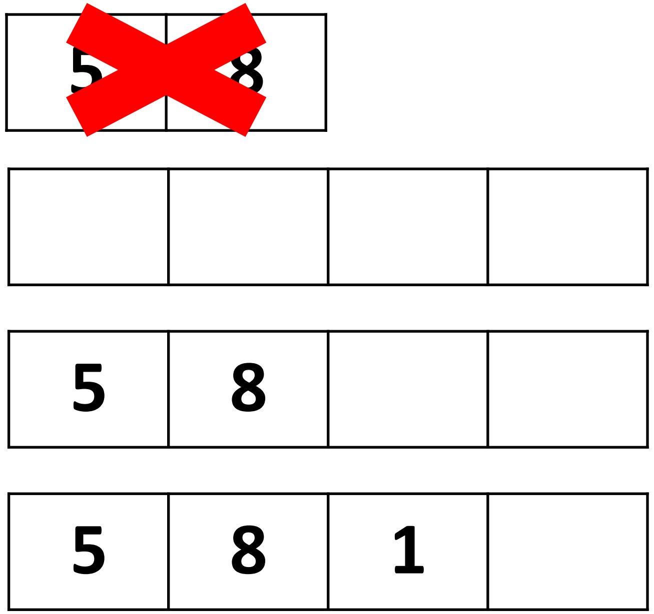
5	8	4	9	6	7		

Inserting an element into dynarray

- Case 1: if size < capacity
  - At least one free spot in data
  - Insert the new element

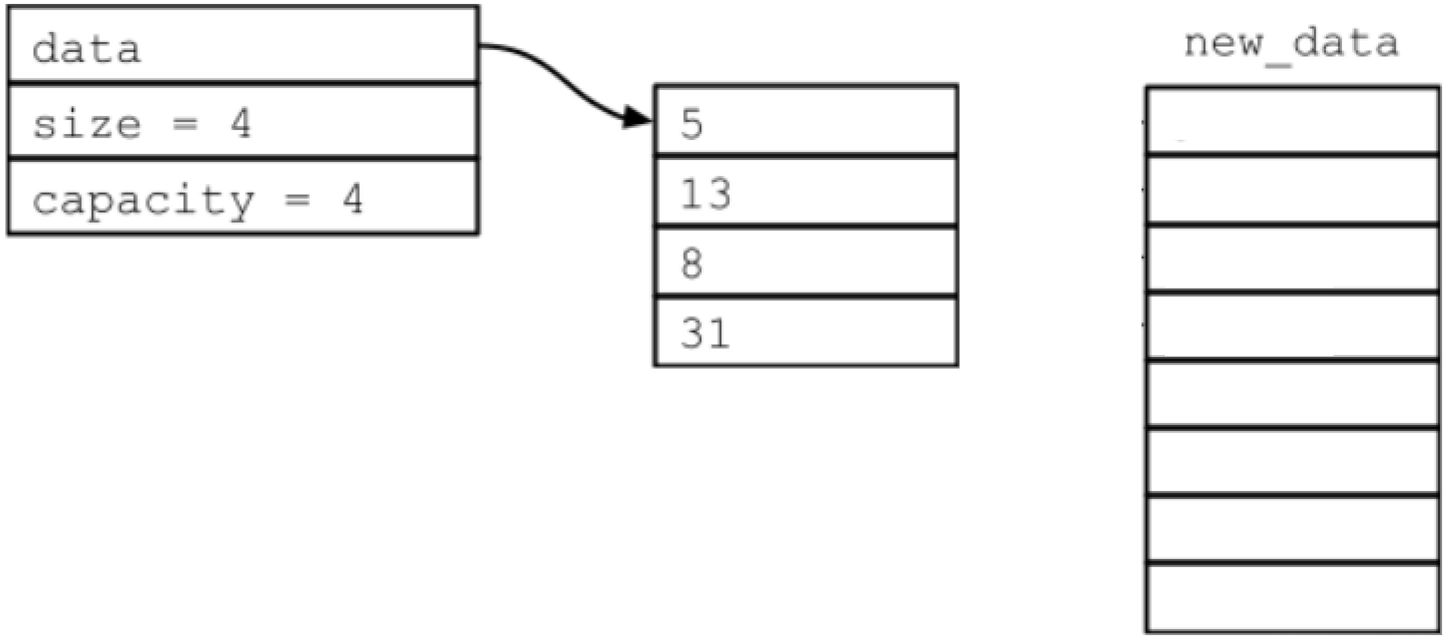


- Case 2: if size == capacity
  - No free spot in data
  - Step 1: allocate a new array that has twice the capacity
  - Step 2: copy all elements from data to new array
  - Step 3: delete the old data array
  - Step 4: Insert the new element



Another Example

- Insert 16 to the following dynamic array:



- Step 1: allocate a new array that has twice the capacity

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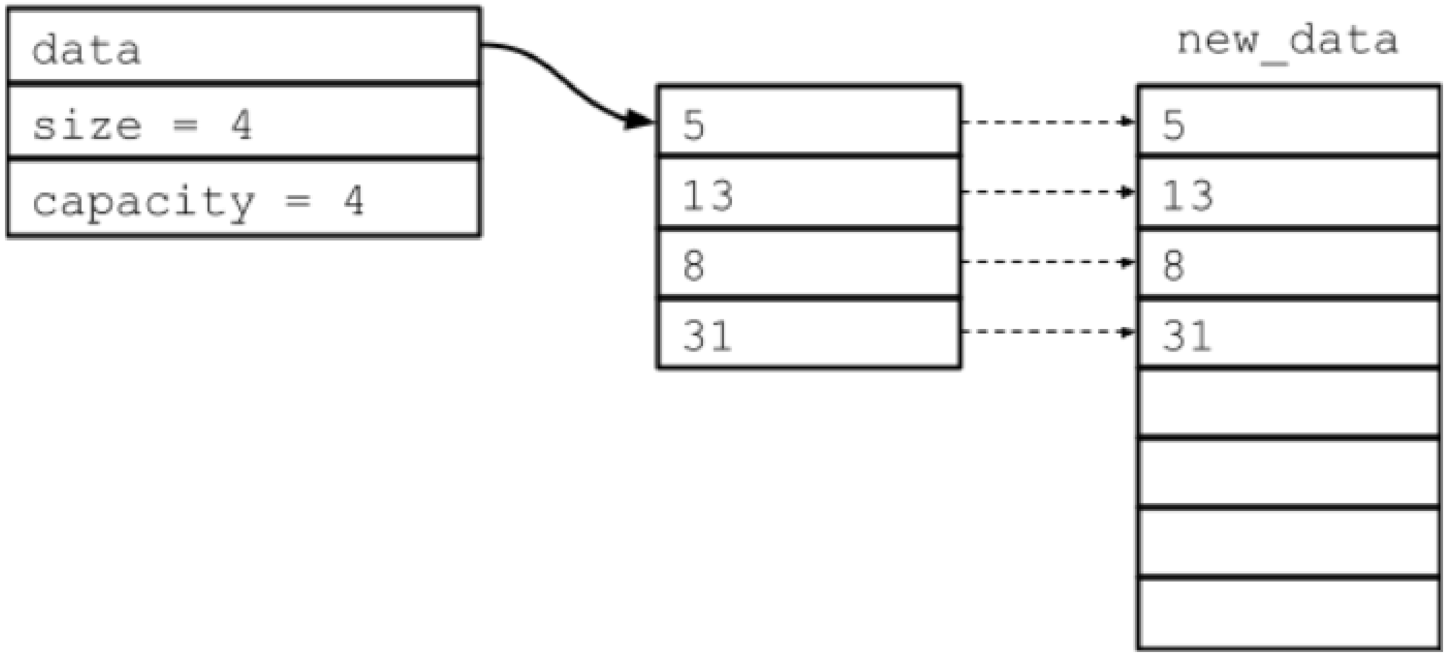

- Step 2: copy all elements from data to new array

Another Example

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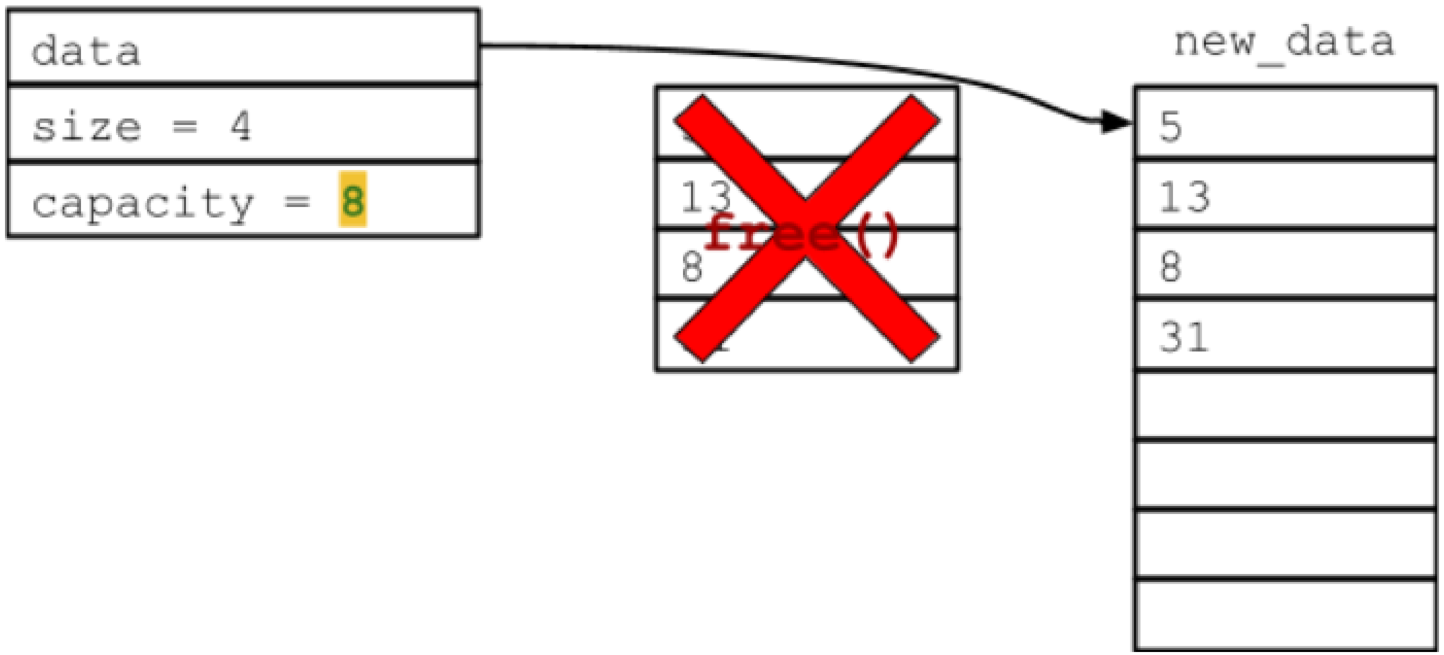

- Step 3: delete the old data array and update data

Another Example

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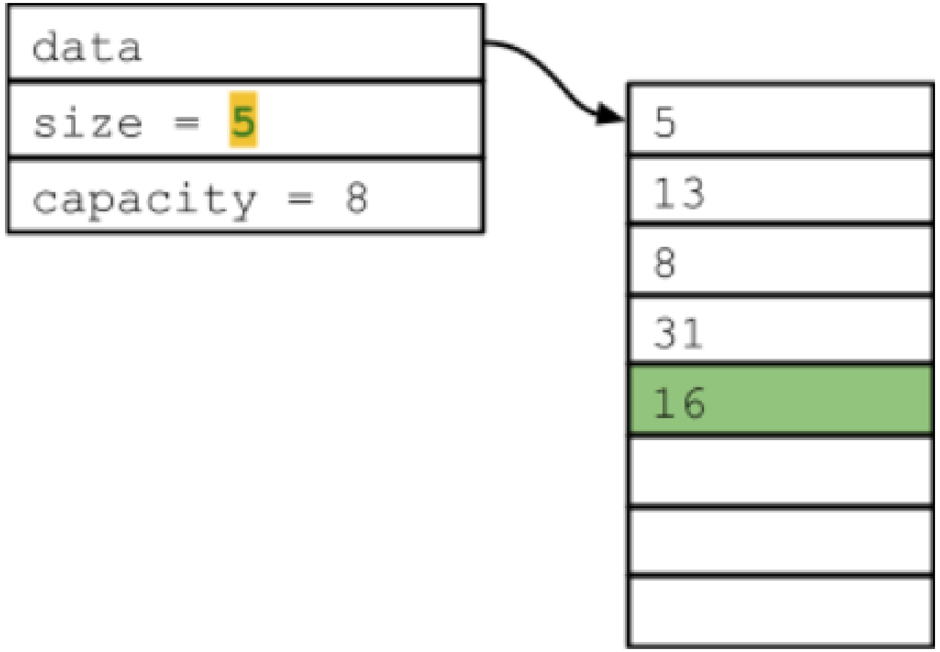

- Step 4: Insert the new element

Lecture Topics:

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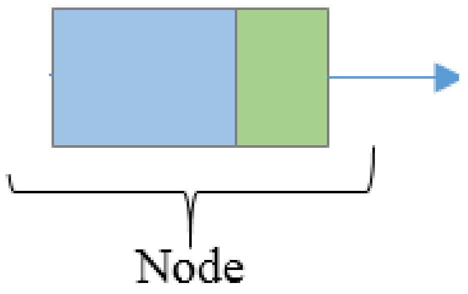
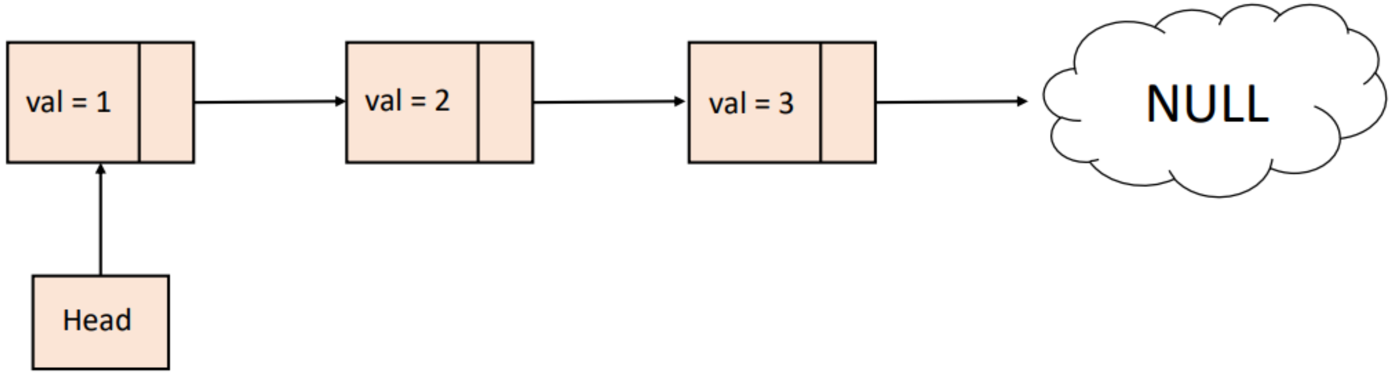
Linked List

```
struct node {
        void* val;
        struct node* next;
};
```



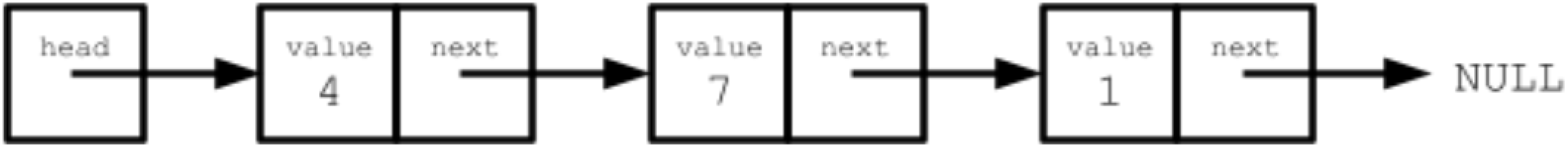
- Linear Data Structure
- Elements in a linked list are stored in nodes and chained together
  - Not in contiguous memory
  - Thus, no random access
- A linked list in which each node points only to the next link in the list is known as a singly-linked list.
  - E.g.:



Linked List

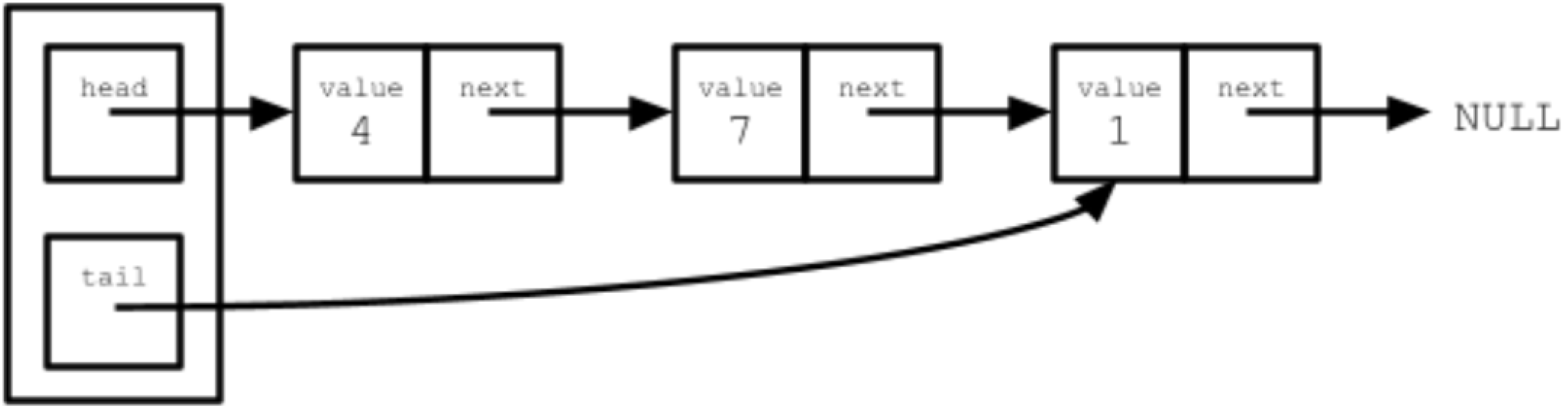
- Always contains as many nodes as it has stored values
  - Add an element → allocate a node, add it to the list
  - Remove an element → free the node from the list

- Many forms of linked list:
  - Keeps track only of the first element in the list, known as head



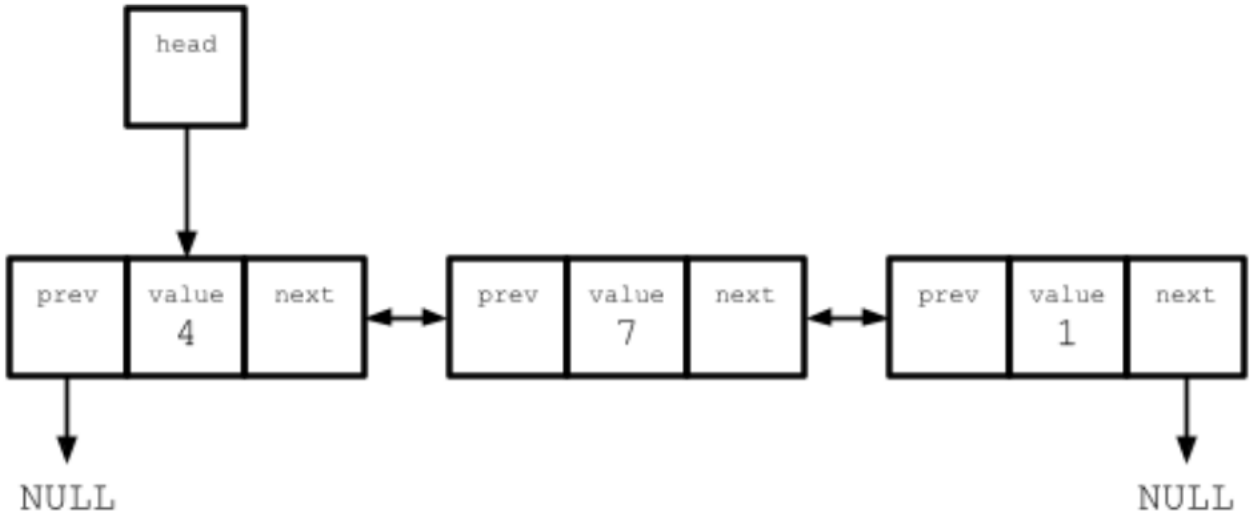
Linked List

- Many forms of linked list:
  - Keeps track only of the first element in the list, known as head
  - Keeps track of both the head of the list and the tail, or last element



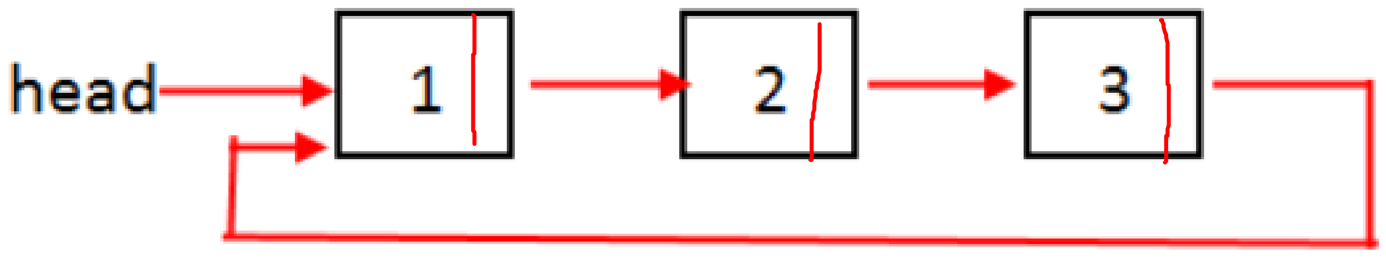
Linked List

- Many forms of linked list:
  - Keeps track only of the first element in the list, known as head
  - Keeps track of both the head of the list and the tail, or last element
  - Each node keeps track of both the *next* link and the *previous* link in the list, known as a doubly-linked list



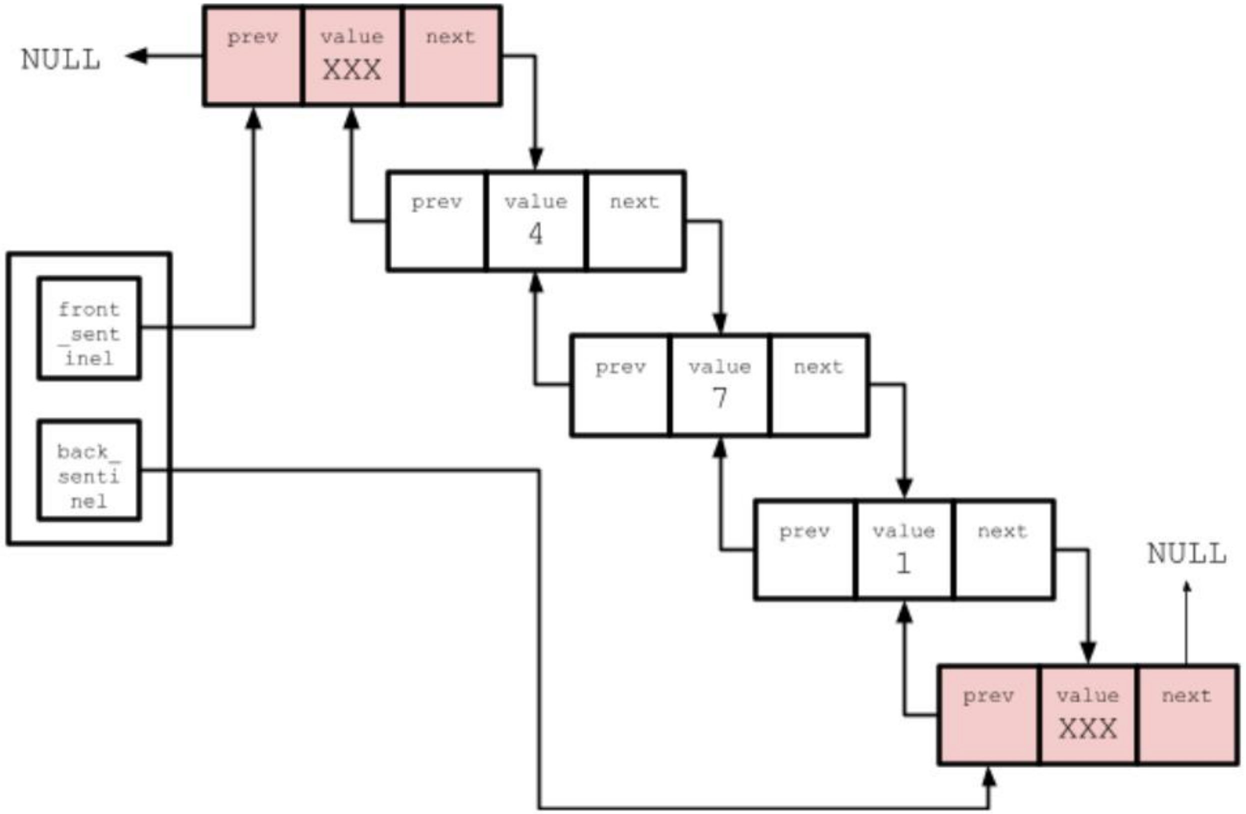
Linked List

- Many forms of linked list:
  - Keeps track only of the first element in the list, known as head
  - Keeps track of both the head of the list and the tail, or last element
  - Each node keeps track of both the *next* link and the *previous* link in the list, known as a doubly-linked list
  - Last node points to the first node, known as circular-linked list



Linked List

- Many forms of linked list:
  - With sentinels, which are special nodes to designate the front/end of the list
    - E.g.: a doubly-linked list using both front and back sentinels



Inserting an element into linked list

- Where can we insert?
  - Front/head
  - End/tail
  - Middle

Inserting an element into linked list

- Insert an element to the front:
  - Construct a node to be inserted, new_node
  - Initialize new_node's next to NULL

  - Case 1:
    - Head is NULL (the list is empty)
    - Simply let head point to new_node

  - Case 2:
    - Head is not NULL (the list is not empty)
    - new_node's next points to the 1st node (head);
    - head point to new_node

Inserting an element into linked list

- Insert an element to the end:
  - Construct a node to be inserted, new_node
  - Initialize new_node's next to NULL

  - Case 1:
    - Head is NULL (the list is empty)
    - Simply let head point to new_node

  - Case 2:
    - Head is not NULL (the list is not empty)
    - Loop to find the last element, last_node
    - last_node's next points to the new_node;

Inserting an element into linked list

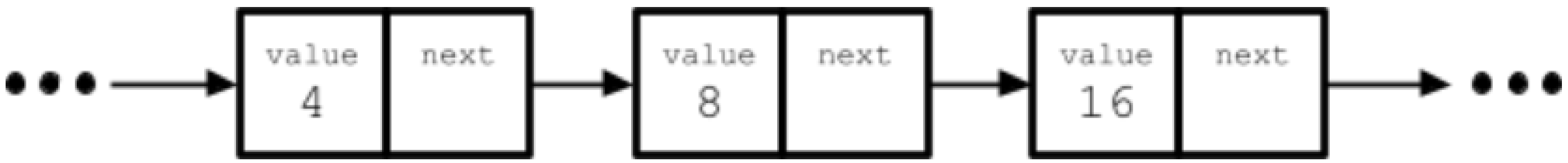
- Insert an element to the middle:
  - Construct a node to be inserted, new_node
  - Initialize new_node’s next to NULL

  - Case 1:
    - Head is NULL (the list is empty)
    - Simply let head point to new_node

  - Case 2:
    - Head is not NULL (the list is not empty)
    - Loop to find the position to insert, after_this_node
    - new_node’s next points to the after_this_node’s next
    - after_this_node’s next points to the new_node

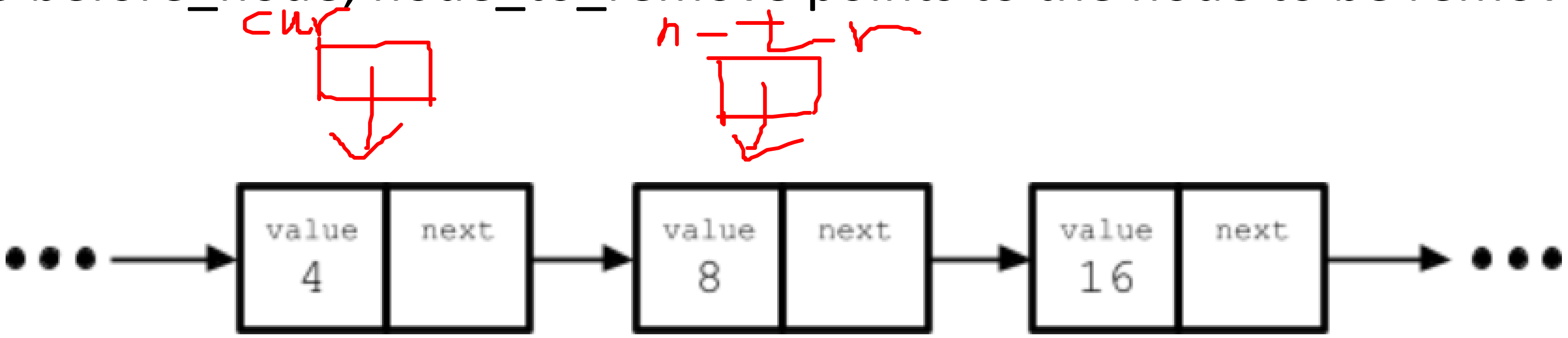
Removing and element from a linked list

- Opposite steps as inserting a new one
- Ex. Assuming the list is not empty, and we want to remove the node containing the value 8:



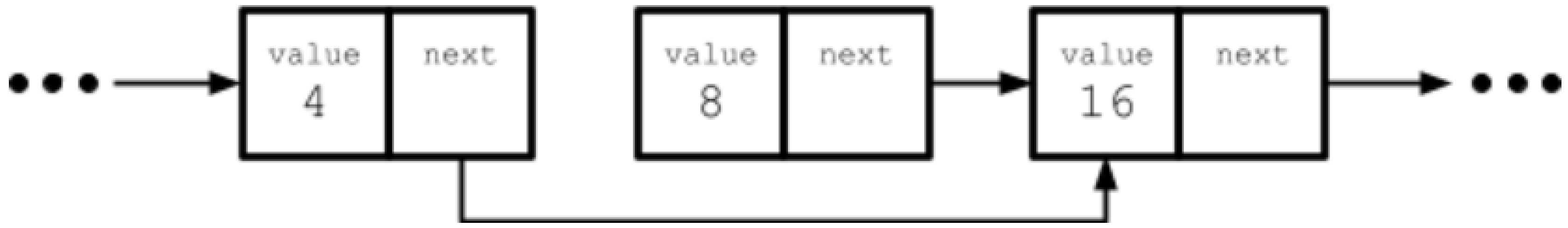
Removing and element from a linked list

- Step 1:
  - Loop to find the node to be removed and the node before, i.e., current points to before_node, node_to_remove points to the node to be removed



Removing and element from a linked list

- Step 2:
  - Set current's next to node_to_remove's next



Removing and element from a linked list

- Step 3:
  - free node_to_remove

Next Lecture:

- Complexity Analysis
  - Big O