Laboratorio de Programación

2016 -2

Juan Camilo Rada[1]

[1]Departamento de Electronica y ciencias de la computación

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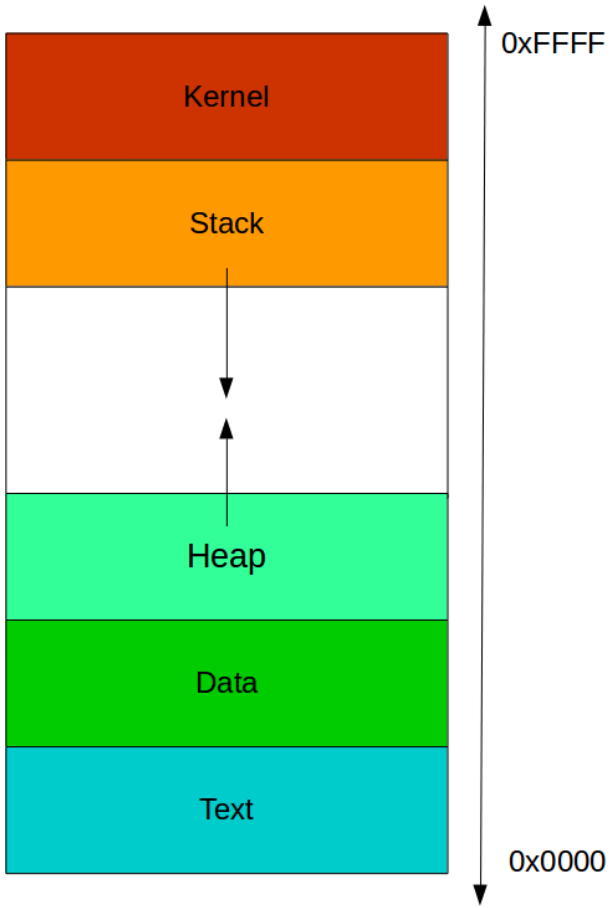
Outline

Outline

Program memory



Dynamic Memory Allocation

Static

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- `double[5] b;`
  We need to specify the size of the array to be allocated

Dynamic Memory Allocation

What if ...

... We are reading a file that may contain hundreds, thousands or just one character

- `char[5000] chars;`
  We are expecting the file to contain less than 5000 chars!

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- What if the file contains just only 1 char?
- We need to *free* memory

Dynamic Memory Allocation

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- We can allocate new memory if we need to store more data in memory
- We can release the memory that is not needed anymore!
- Allocated memory is accessed using Pointers
- `stdlib.h` provide functions to work with dynamic memory

Outline

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void* malloc (size_t size);
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The `malloc` function

- Allocate a new block of memory

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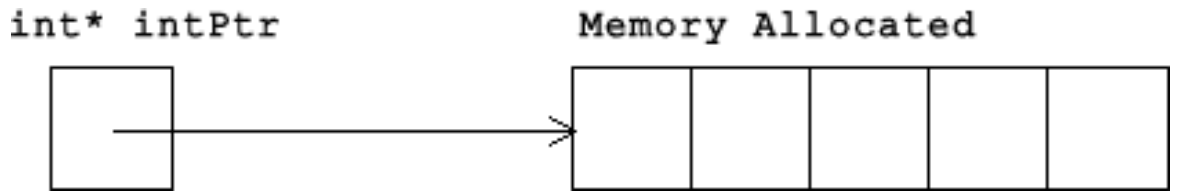

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Dynamic Memory Allocation

Test the code

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#include <stdio.h>
#include <stdlib.h>

int main() {
    int pos;
    int i = 0;
    printf("Positions to be allocated ");
    scanf("%d", &pos);

    int* intPtr = (int* ) malloc(sizeof(int)*pos);

    for(i=0; i<pos; i++)
        intPtr[i] = 20;

    for(i=0; i<pos; i++)
        printf("int[%i] = %i\n", i, intPtr[i]);
}
```

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- `(int* )`
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The `calloc` function

- Allocate new array with `num` positions, each of them `size` bytes long

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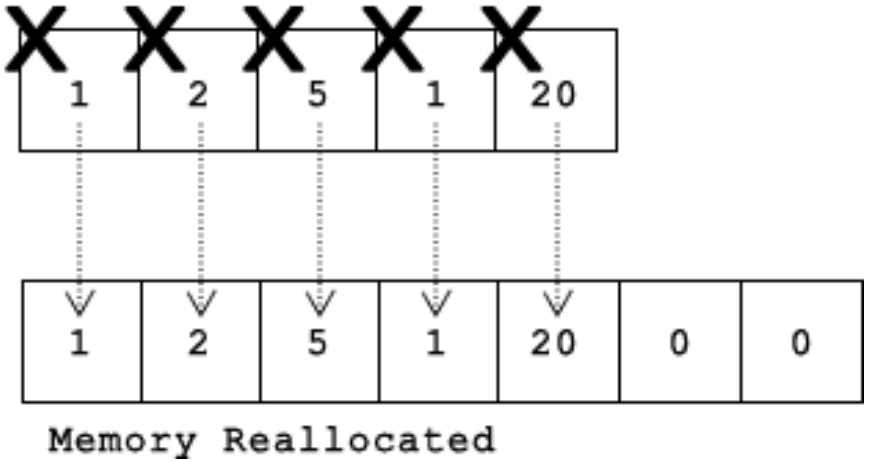

The `realloc` function

- Helps to allocate more memory if needed

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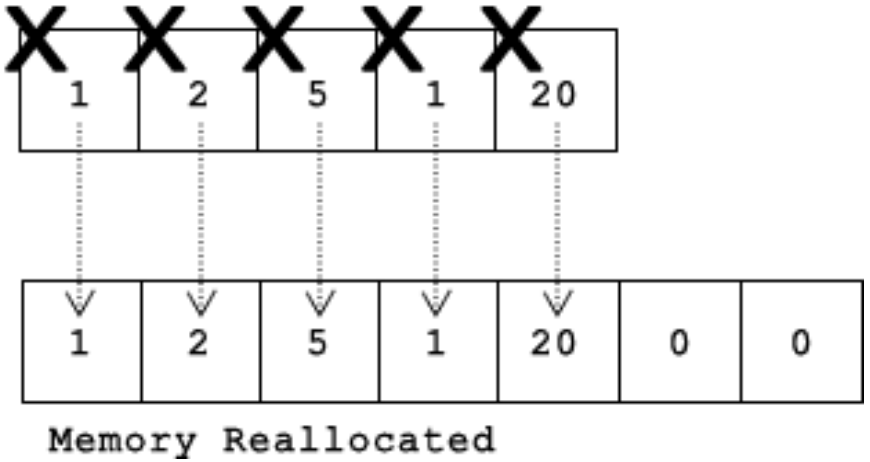

The `realloc` function

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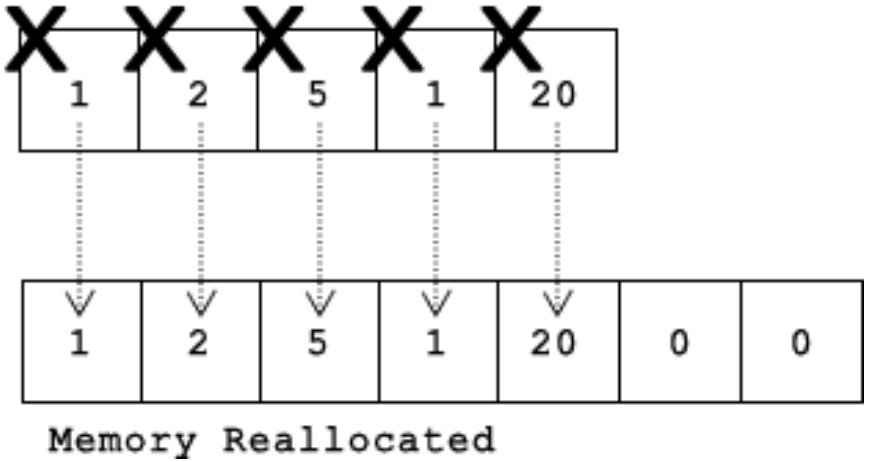

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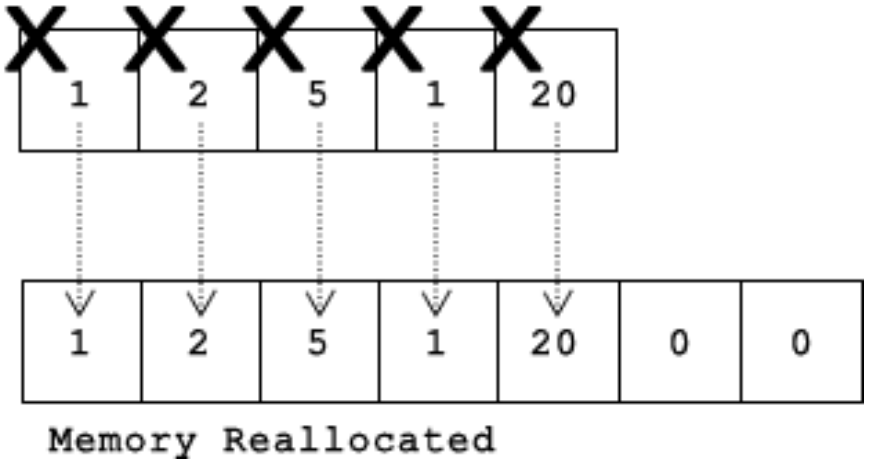

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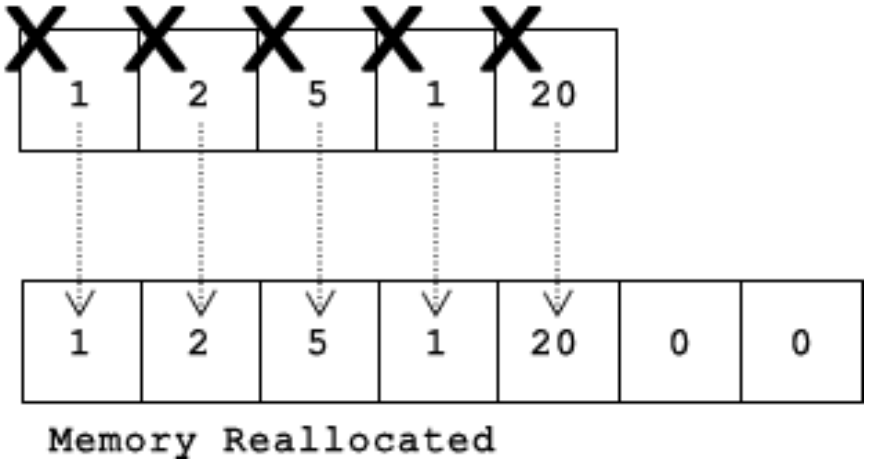

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void* realloc (void* ptr, size_t size);
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Dynamic Memory Allocation

Test the code

```
#include <stdio.h>
#include <stdlib.h>
int main() {
    int* ptr = NULL;
    int count = 0, number = 0, ver = 1, i = 0;
    while(ver)
    {
        printf("Give me an integer: ");
        scanf("%d", &number);
        count++;
        ptr = (int*) realloc(ptr, count*sizeof(int));
        ptr[count-1] = number;

        printf("Do you want more numbers 1/0? ");
        scanf("%d", &ver);
    }
    for(i=0; i<count; i++)
        printf("int[%i] = %i\n", i, ptr[i]);
```

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Dynamic Memory Allocation

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void free (void* ptr);
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The free function

- Deallocate a block of memory, making it available for future use

Dynamic Memory Allocation

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void free (void* ptr);
```

The `free` function

- Deallocate a block of memory, making it available for future use
- `void* ptr`
  Pointer to the block of memory to be deallocated
- The block of memory to be deallocated, had to be allocated with `malloc`, `calloc` or `realloc`, otherwise it will face an unexpected behaviour

Outline

Dynamic Memory Allocation - Matrix

Matrix

- We can also allocate matrices with dynamic memory

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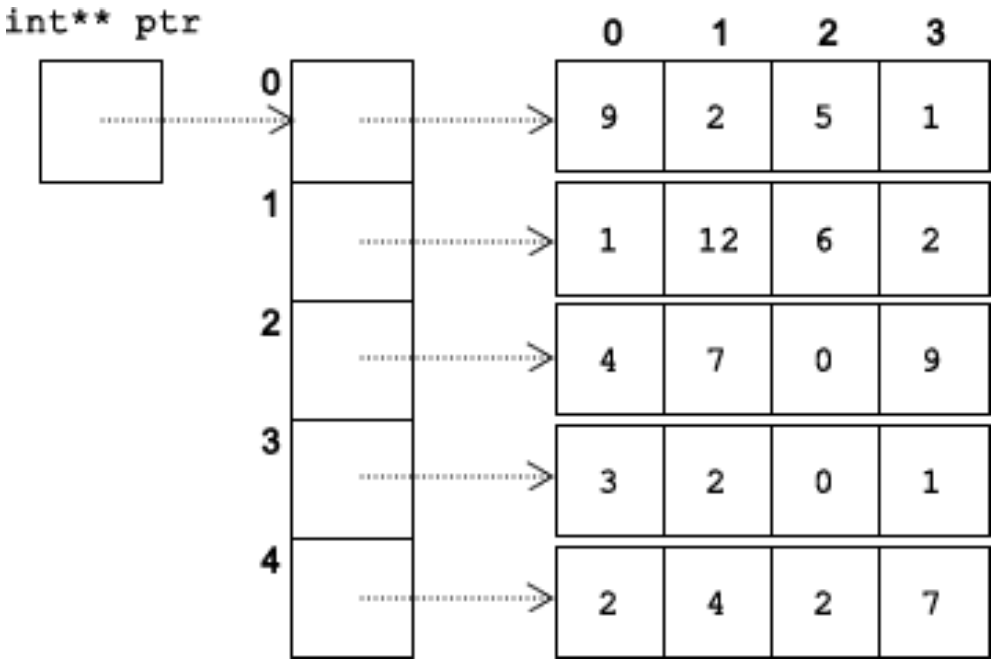
  Double pointers helps to accomplish the allocation!
- *A double pointer is a pointer which points to an array of pointers!*
- The pointers in the *Array of pointers* are allocated using `malloc`, `calloc` or `realloc`
- `ptr[0][2]`
  We can access every position with the double bracket operator

Dynamic Memory Allocation - Matrix



Dynamic Memory Allocation - Matrix

```
int** ptr = calloc(rows, sizeof(int));
for(i=0; i<rows; i++)
    ptr[i] = calloc(cols, sizeof(int));
```

Statement

1. `int** ptr = calloc(rows, sizeof(int));`
   The array of pointers has to be allocated
2. `ptr[i] = calloc(cols, sizeof(int));`
   We allocate every row as a dynamic array

Dynamic Memory Allocation

Test the code

```c
#include <stdio.h>
#include <stdlib.h>

int main() {
    int i=0, rows = 5, cols = 4;

    int** ptr = calloc(rows, sizeof(int));
    for(i=0; i<rows; i++)
        ptr[i] = calloc(cols, sizeof(int));

    ptr[0][4] = 35;

    printf("%i", ptr[0][4]);
}
```

Dynamic Memory Allocation

Let's write some code

Using the `malloc`, `calloc` and `realloc` functions, write the next procedures

- `addColumn` - Add a new column to the dynamic matrix

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- `addRow` - Add a new row to the dynamic matrix

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Let's write some code

Using the `malloc`, `calloc` and `realloc` functions, write the next procedures

- `addColumn` - Add a new column to the dynamic matrix
- `addRow` - Add a new row to the dynamic matrix
- `read`
  A function which reads from the keyboard: The number of rows, the number of columns, the value to be added in every position. Returns the double-pointer to the matrix

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Let's write some code

Using the `malloc`, `calloc` and `realloc` functions, write the next procedures

- `addColumn` - Add a new column to the dynamic matrix
- `addRow` - Add a new row to the dynamic matrix
- `read`
  A function which reads from the keyboard: The number of rows, the number of columns, the value to be added in every position. Returns the double-pointer to the matrix
- `print`
  A procedure which receives a double pointer, the rows and columns and prints in the screen all the values of the matrix

Outline

Dynamic Memory Allocation - Structs

Matrix

- We can also allocate structures with dynamic memory

Dynamic Memory Allocation - Structs

Matrix

- We can also allocate structures with dynamic memory
- We only need to allocate the necessary space required by the structure

Dynamic Memory Allocation - Structs

Test the code

```c
#include <stdio.h>
#include <stdlib.h>

struct Person {
    char name[100];
    char lastName[100];
    int age;
};

int main()
{
    struct Person* myPerson = malloc(sizeof(struct Person));
    myPerson->age = 20;
    printf("Age = %d", myPerson->age);
}
```

Dynamic Memory Allocation - Structs

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struct Person* myPerson = malloc(sizeof(struct Person));
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Dynamic structs

- `struct Person* myPerson`
  A pointer to a Person struct

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Dynamic structs

- `struct Person* myPerson`
  A pointer to a `Person` struct
- `malloc(sizeof(struct Person))`
  Memory allocation. Get the enough memory space to store a `Person`

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Dynamic structs

- `struct Person* myPerson`
  A pointer to a `Person` struct
- `malloc(sizeof(struct Person))`
  Memory allocation. Get the enough memory space to store a `Person`
- `myPerson->age`
  We use now the `->` operator to access a member of the structure

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Basics

- Is a characteristic of the *Third Generation* of programming languages ▸ Read More!

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- The pointer points to executable code within memory
- The function can be executed just by calling the pointer as a normal function
- Invocation is known as *Indirect Call*
- Functions passed as an argument are widely known as *Callbacks*
- The function is expected to be called back at some convenient time

Function Pointers

```
int myFunction(double a, char b)
```

Function Pointers

```
int myFunction(double a, char b)
int (*pointer) (double, char)
```

Declaring a pointer

- `int (*pointer)` → `int myFunction`
  The pointer type has to be equal to the function return type

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  Types of the function members

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- `int (*pointer) (double, char) = myFunction`
  The pointer points to `myFunction`

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- `(double, char)` → `(double a, double b)`
  Types of the function members
- `int (*pointer) (double, char) = myFunction`
  The pointer points to `myFunction`
- `void process(void (*funcp)(int), int a, int b)`
  A function which receives a function as a parameter

Function Pointers

Test the code

```c
#include <stdio.h>

void callback(int value)
{
    printf("This Callback function prints the value = %i", value);
}
void process(void (*funcp)(int), int a, int b)
{
    int c = a + b;
    funcp(c);
}
int main()
{
    void (*functionPointer)(int);
    functionPointer = callback;
    process(functionPointer, 2, 3);
}
```

Function Pointers

Test the code

```
#include <stdio.h>
void callback()
{
    printf("The process has finished!!!\n");
}
void process(void (*funcp)(), int *a, int b)
{
    *a = (*a * *a) + b;
    funcp();
}
int main()
{
    int var = 5;
    void (*functionPointer)();
    functionPointer = callback;
    process(functionPointer, &var, 3);
    printf("a = %d", var);
}
```

Function Pointers

Test the code

```c
#include <stdio.h>
int sumCallback(int a, int b)
{
    return a + b;
}
void process(int (*funcp)(int, int), int a, int b)
{
    printf("a = %d, b = %d, res = %d", a, b, funcp(a, b));
}
int main()
{
    int (*functionPointer)(int, int);
    functionPointer = sumCallback;
    process(functionPointer, 5, 3);
}
```

Function Pointers

```
int* map(int (*fun)(int value), int *array, int size)
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The map function

- Is a *High-order* function

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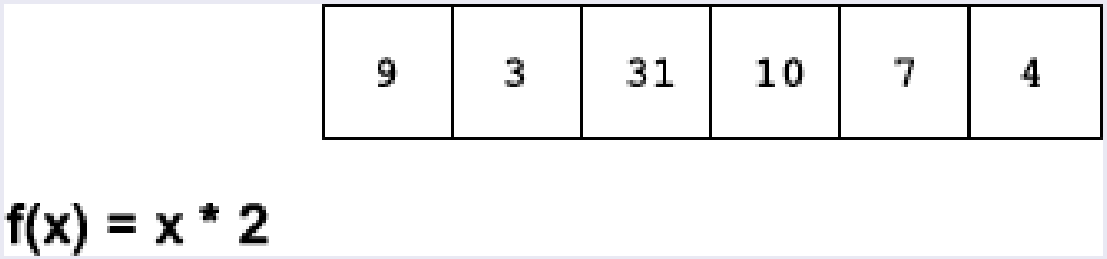
The `map` function

- Is a *High-order* function
- A high-order function is the one who takes functions as arguments
- The `map` function applies the input function over all the elements in an array
- *Keep in mind:* It works also for sequential *containers*

Function Pointers

The map function - How it works?



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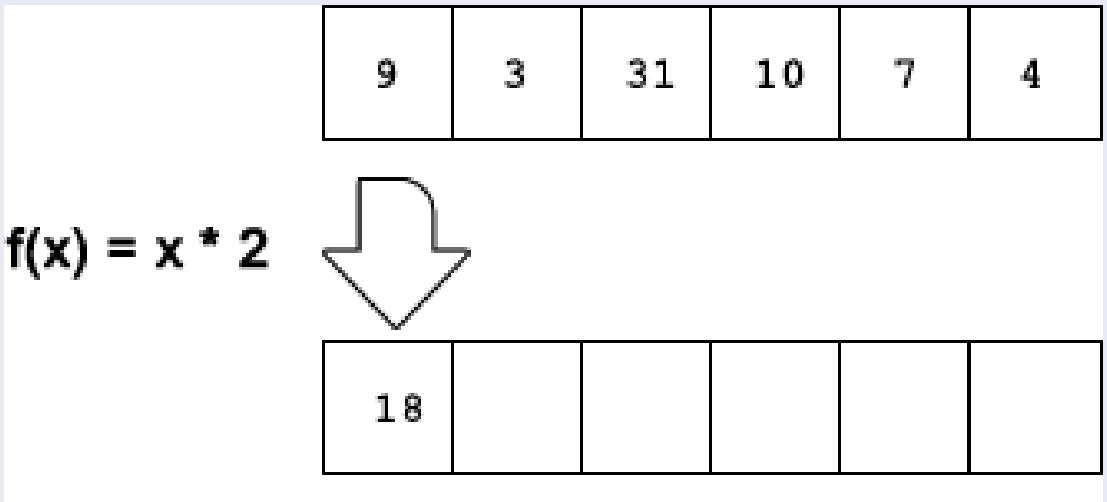

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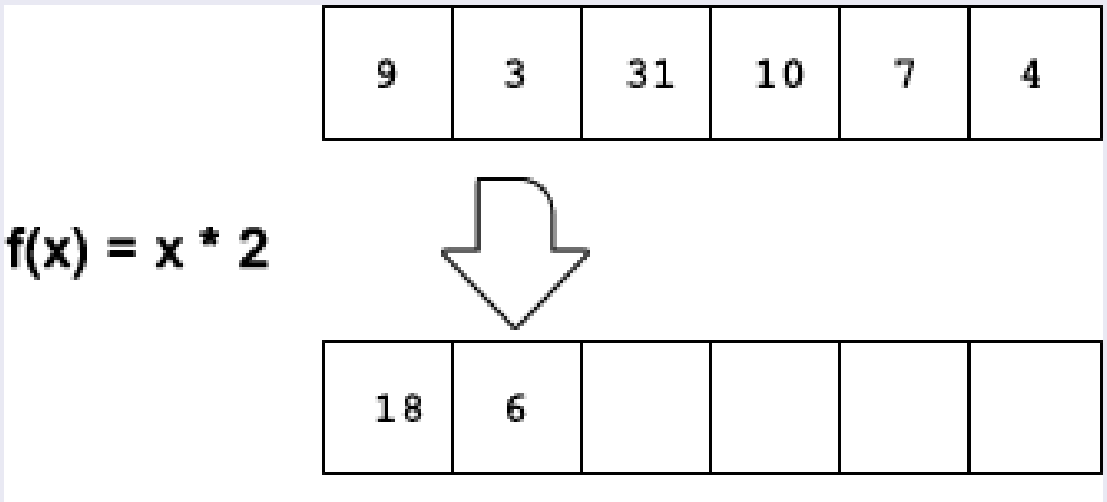

Function Pointers

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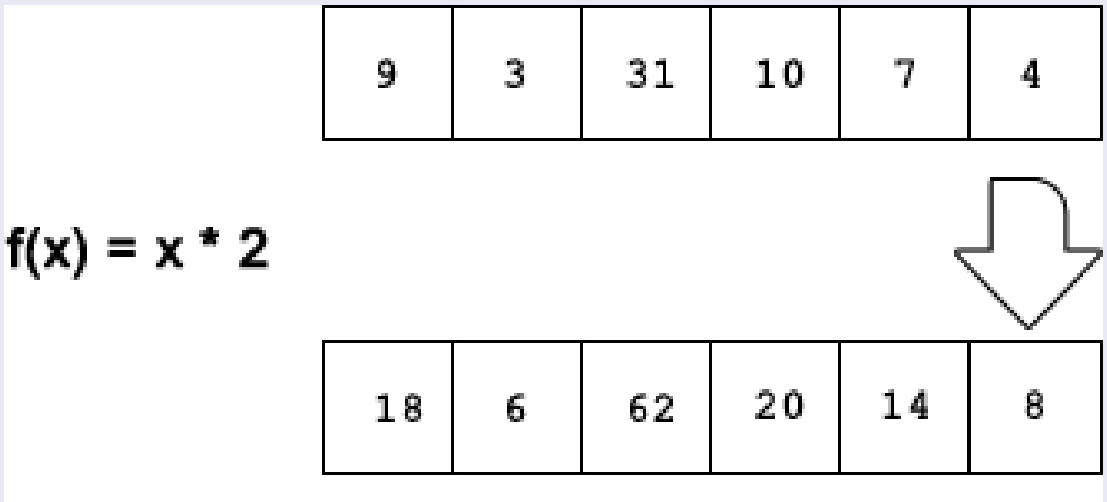


Function Pointers

The map function - Implementation

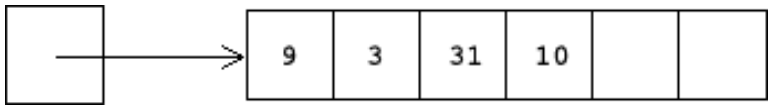
```
int* map(int (*funPtr)(int), int* ptr, int size)
{
    int* ptrRes = calloc(size, sizeof(int));
    for (int i=0; i<size; i++)
    {
        *(ptrRes+i) = funPtr(ptr[i]);
    }
    return ptrRes;
}
```

Function Pointers - Test the code with the map function

```c
#include <stdio.h>
#include <stdlib.h>

int getDouble(int a)
{
    return a*2;
}

int main()
{
    int *a = calloc(2, sizeof(int));
    int (*fun)(int) = getDouble;
    a[0] = 5;
    a[1] = 9;

    int* array = map(fun, a,2);

    printf("%d, %d", array[0], array[1]);
}
```

Outline

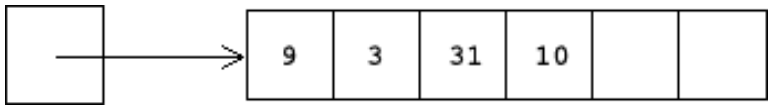
Array List



Definition

An Array List is the most simple definition of a dynamic array.

Array List



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- Has a fixed size, but has the ability to be expanded or contract when is required

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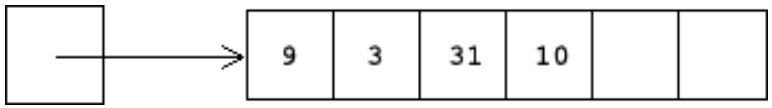

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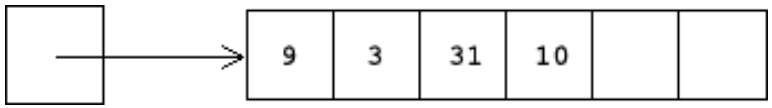

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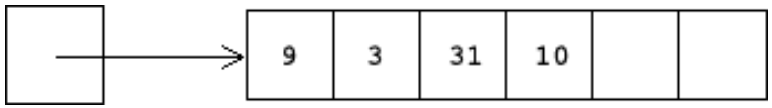

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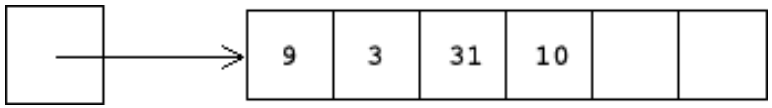

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- Values are contiguous in memory

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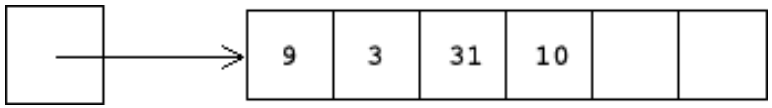

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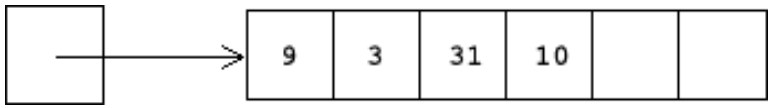
Array List



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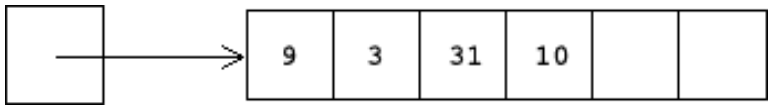

Definition

- Values are contiguous in memory
- We have to iterate over the whole list to get a value
- Values are added at the end of the array list
- Delete values operation is a high complexity job!

Array List

Operations

- `insert`
  Input: A pointer to the array list and the element to insert
  Do: Inserts the element at the last position of the list

Array List

Operations

- `insert`
  Input: A pointer to the array list and the element to insert
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  Input: A pointer to the array list and the element to delete
  Do: Search for the element, and delete the element

Array List

Operations

- `insert`
  Input: A pointer to the array list and the element to insert
  Do: Inserts the element at the last position of the list
- `delete`
  Input: A pointer to the array list and the element to delete
  Do: Search for the element, and delete the element
- `valueAt`
  Input: A pointer to the array list and the position to retrieve
  Do: Search for the element, and return the value at the position

Outline

Array List - Building

The `ArrayList` struct

Contains the next fields:

- `int capacity`
  The capacity of the Array List

Array List - Building

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Contains the next fields:

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- `int elements`
  Number of elements in the Array List

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Contains the next fields:

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  The capacity of the Array List
- `int elements`
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- `int increment`
  The number of positions that the array list will expand when adding a value exceeds the capacity

Array List - Building

The `ArrayList` struct

Contains the next fields:

- `int capacity`
  The capacity of the Array List
- `int elements`
  Number of elements in the Array List
- `int increment`
  The number of positions that the array list will expand when adding a value exceeds the capacity
- `int* basicArray`
  The number of positions that the array list will expand when adding a value exceeds the capacity

Array List - Insert

Algorithm

1. Let `pointer` a pointer to the Array List structure, and `data` an integer value to be inserted

Array List - Insert

Algorithm

1. Let `pointer` a pointer to the Array List structure, and `data` an integer value to be inserted
2. Check if the number of elements in the array is greater than the Array List capacity

Array List - Insert

Algorithm

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2. Check if the number of elements in the array is greater than the Array List capacity
3. If so, we have to *EXPAND* the array list. Otherwise, no

Array List - Insert

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Array List - Insert

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5. Increase the value of the `elements` field

Array List - Expand

Algorithm

To expand the size of the array list, we just need to reallocate the `basicArray` into a bigger one

Array List - Expand

Algorithm

To expand the size of the array list, we just need to reallocate the `basicArray` into a bigger one

1. If the expand is needed, reallocate (Using the `realloc` function) the `basicArray`, with the new size = `capacity` + `increment`

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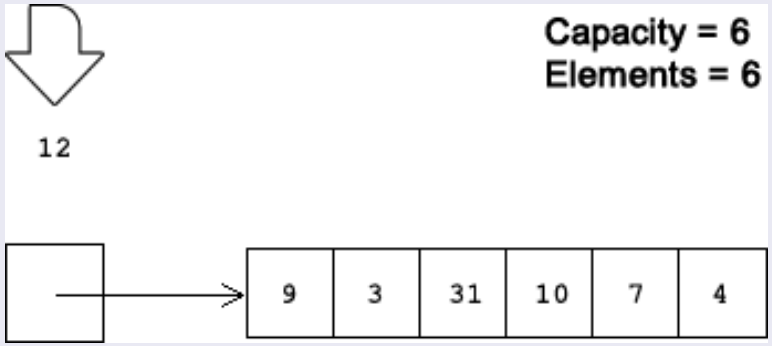
To expand the size of the array list, we just need to reallocate the `basicArray` into a bigger one

1. If the expand is needed, reallocate (Using the `realloc` function) the `basicArray`, with the new size = `capacity` + `increment`
2. Update the `capacity` field

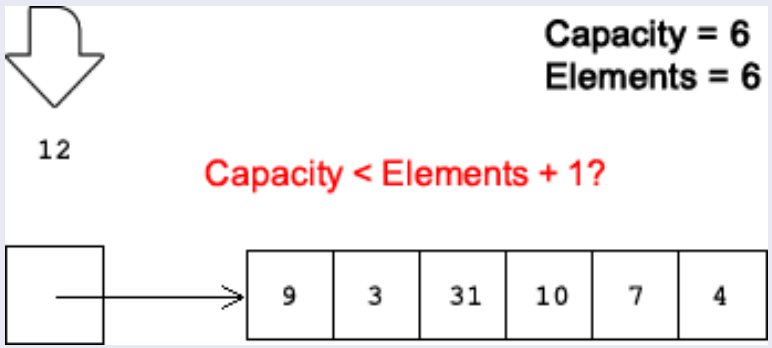
Array List - Insert

Insert an element - Example



Array List - Insert

Insert an element - Example



Array List - Insert

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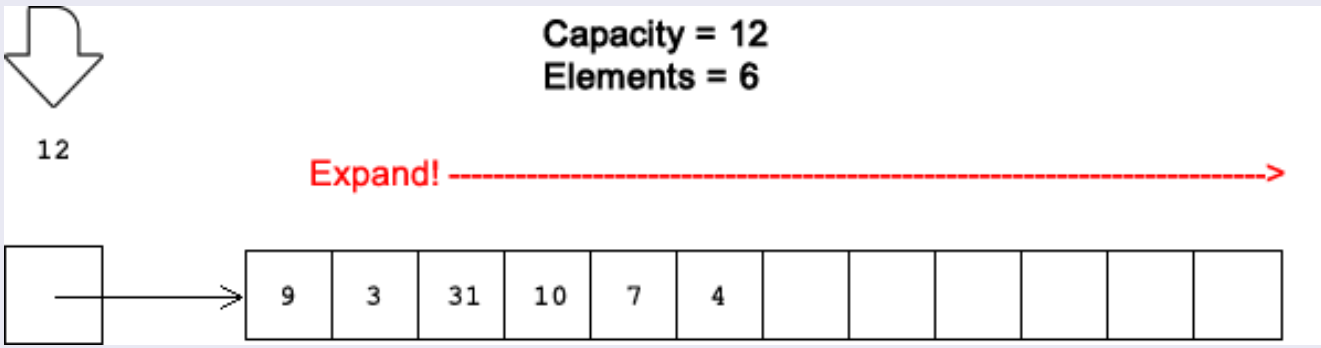

Array List - Insert

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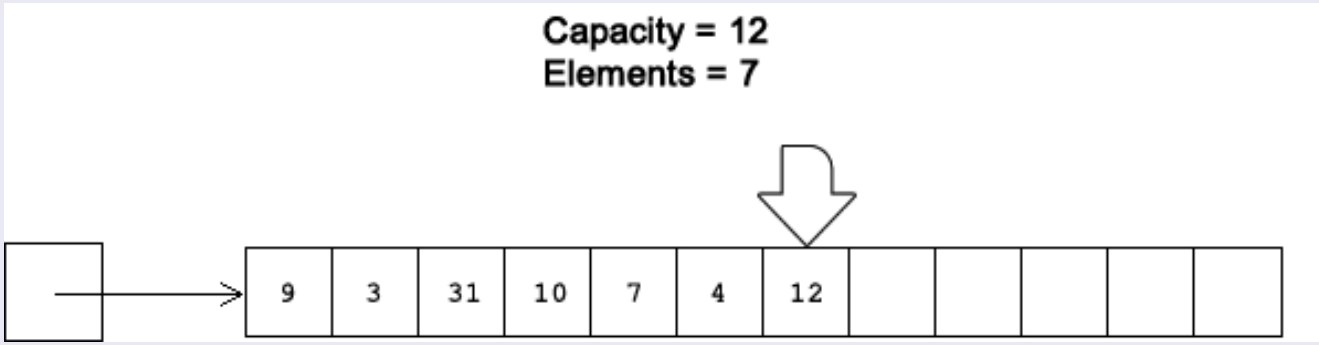

Array List - Delete

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1. Let `pointer` a pointer to the array list structure, and `data` an integer value to be deleted
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6. Check if the array needs to be *CONTRACTED* if so, contract

Array List - Contract

Algorithm

To contract the size of the array list, we just need to reallocate the `basicArray` into a smaller one

Array List - Contract

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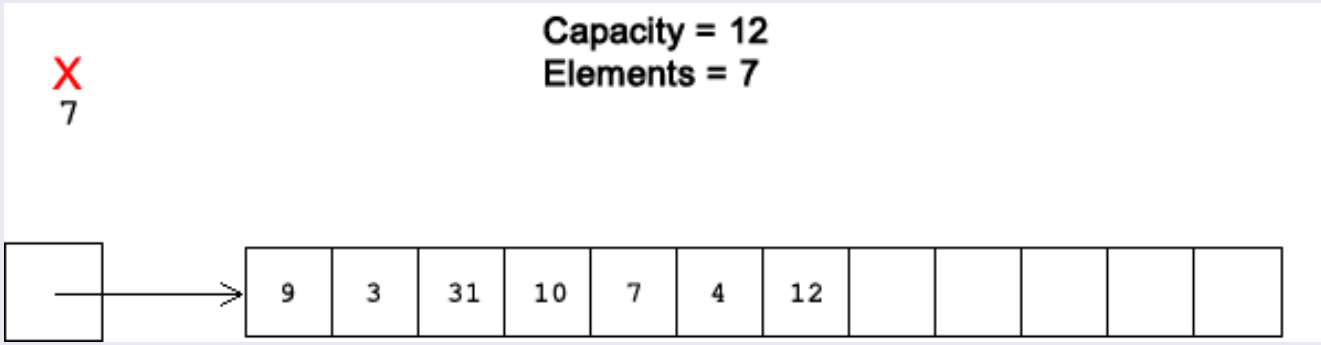
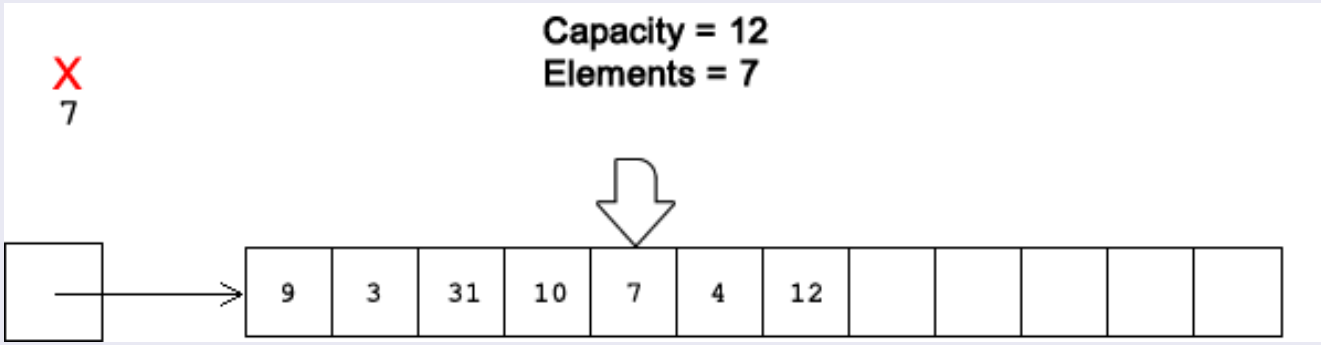
Array List - Delete

Delete an element - Example



Array List - Delete

Delete an element - Example



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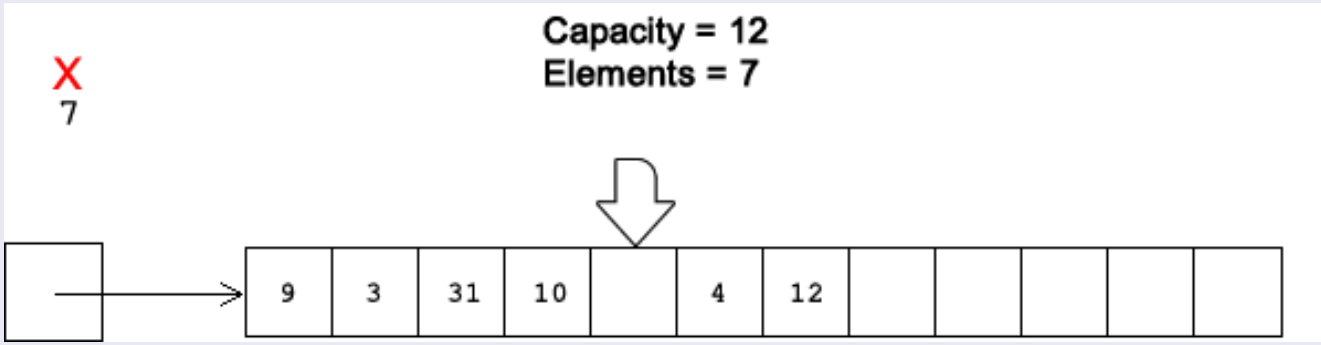

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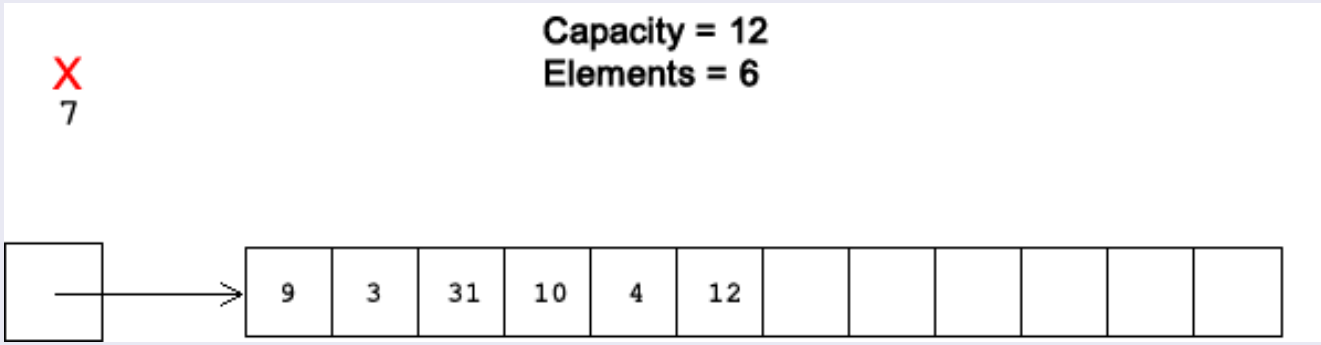

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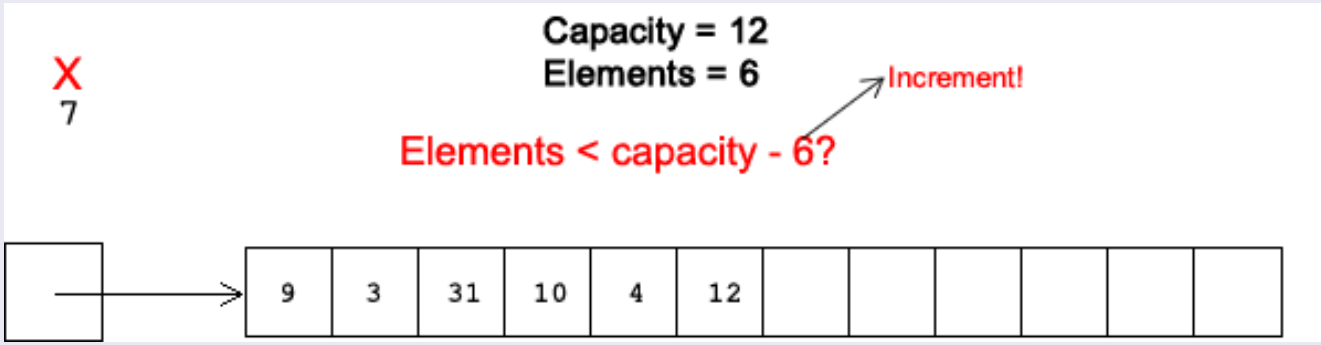

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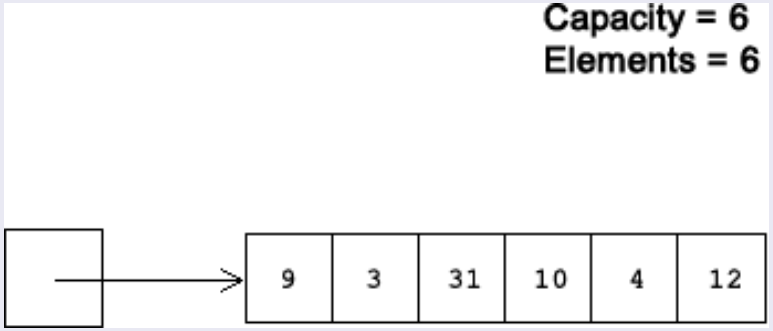

Array List - Find

ValueAt

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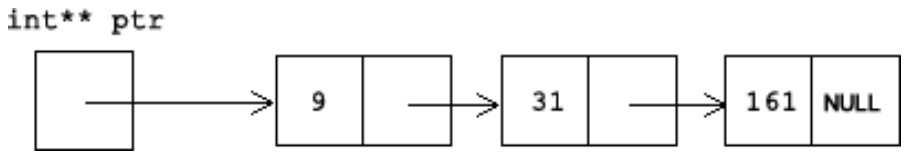
Outline

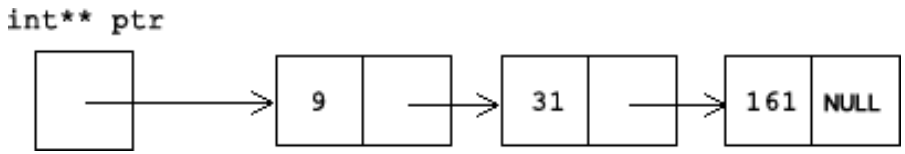
Linked List



Definition

A Linked List is a collection of structures connected by pointers (links).

Linked List



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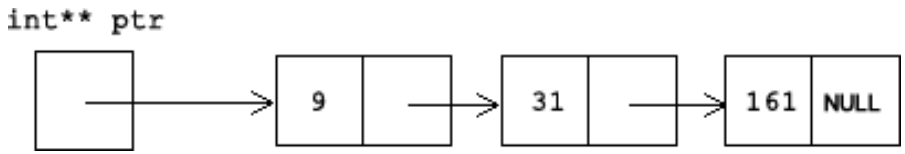

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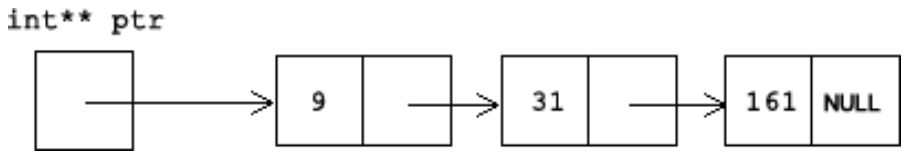

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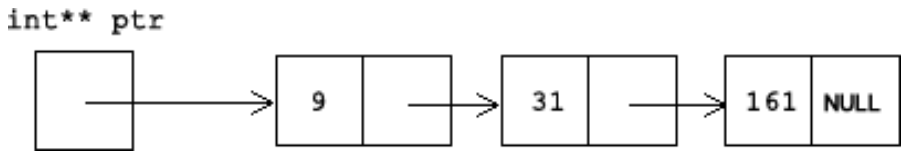

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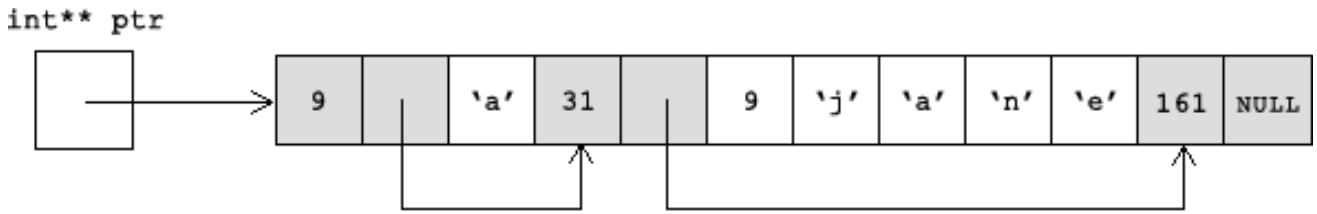
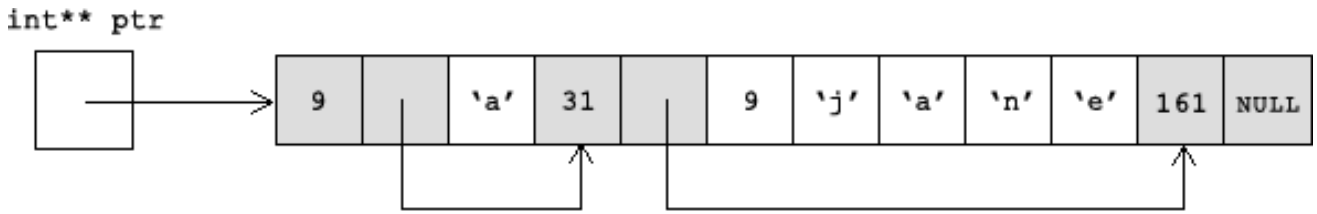


Definition

- Values are not contiguous in memory

Linked List



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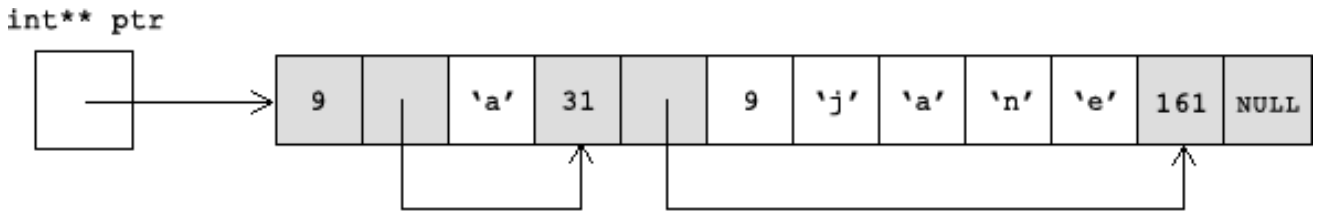

Definition

- Values are not contiguous in memory
- We have to iterate over the whole list to get a value
- To insert a value is just enough to create a new node and change the involved *links*

Linked List

Operations

- `insert`
  Input: A pointer to the linked list and the element to insert
  Do: Inserts the element at the last position of the list

Linked List

Operations

- `insert`
  Input: A pointer to the linked list and the element to insert
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- `delete`
  Input: A pointer to the linked list and the element to delete
  Do: Search for the element, and delete the node

Linked List

Operations

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  Do: Inserts the element at the last position of the list
- `delete`
  Input: A pointer to the linked list and the element to delete
  Do: Search for the element, and delete the node
- `find`
  Input: A pointer to the linked list and the element to search
  Do: Search for the element node per node, and return `1` if the element was found, otherwise `0`

Outline

Linked List - Building

The `Node` struct

Contains the next fields:

- `int value`
  Where the value will be stored
- `Node* next`
  A pointer to the next node

Linked List - Insert

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be inserted

Linked List - Insert

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be inserted
2. Check if the pointer to the `next` position is null, if so, check the next step, otherwise move the pointer to the `next` reference and keep it searching

Linked List - Insert

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be inserted
2. Check if the pointer to the `next` position is null, if so, check the next step, otherwise move the pointer to the `next` reference and keep it searching
3. Allocate a new `Node` in the pointer to `next`

Linked List - Insert

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be inserted
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3. Allocate a new `Node` in the pointer to `next`
4. Assign the value to the node in `next`

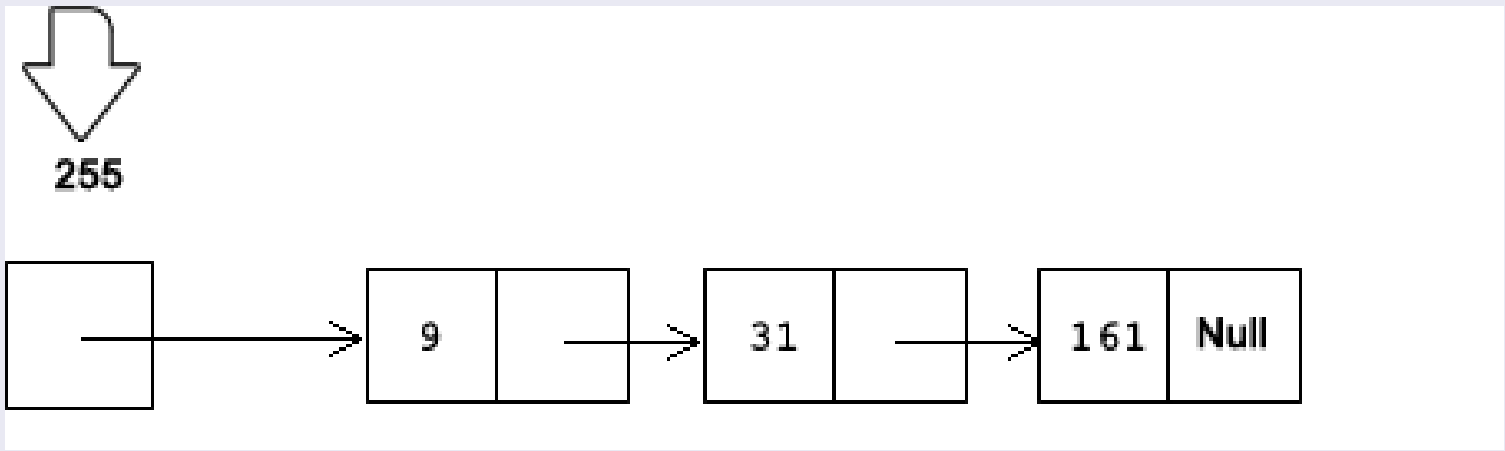
Linked List - Insert

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be inserted
2. Check if the pointer to the `next` position is null, if so, check the next step, otherwise move the pointer to the `next` reference and keep it searching
3. Allocate a new `Node` in the pointer to `next`
4. Assign the value to the node in `next`
5. Points to null the `next` pointer of the `next` node

Linked List - Insert

Insert a node - Example



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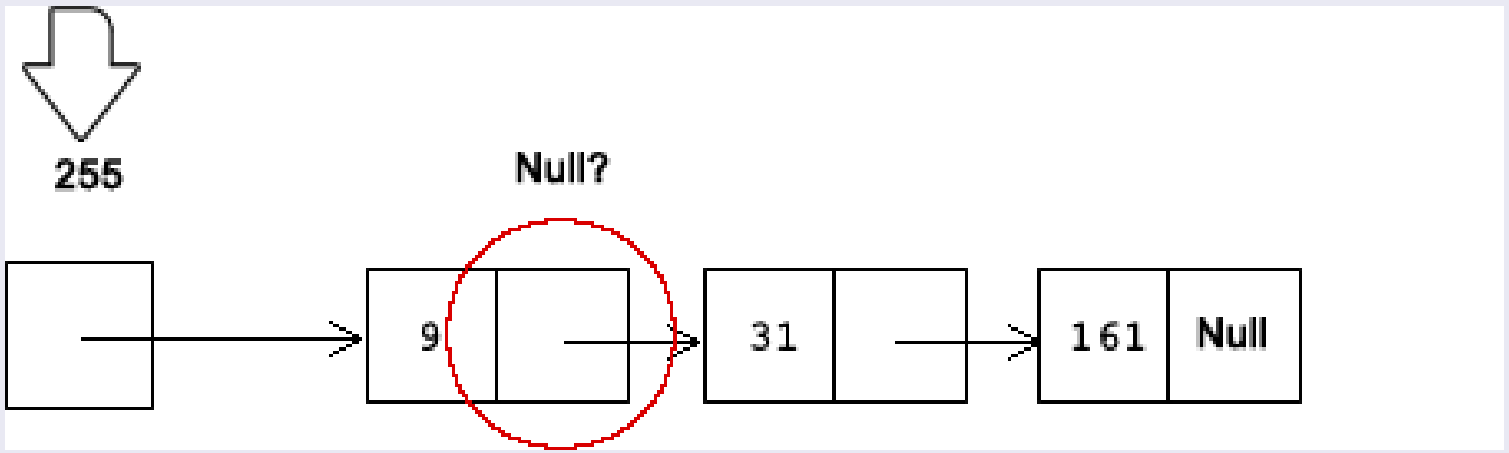

Linked List - Insert

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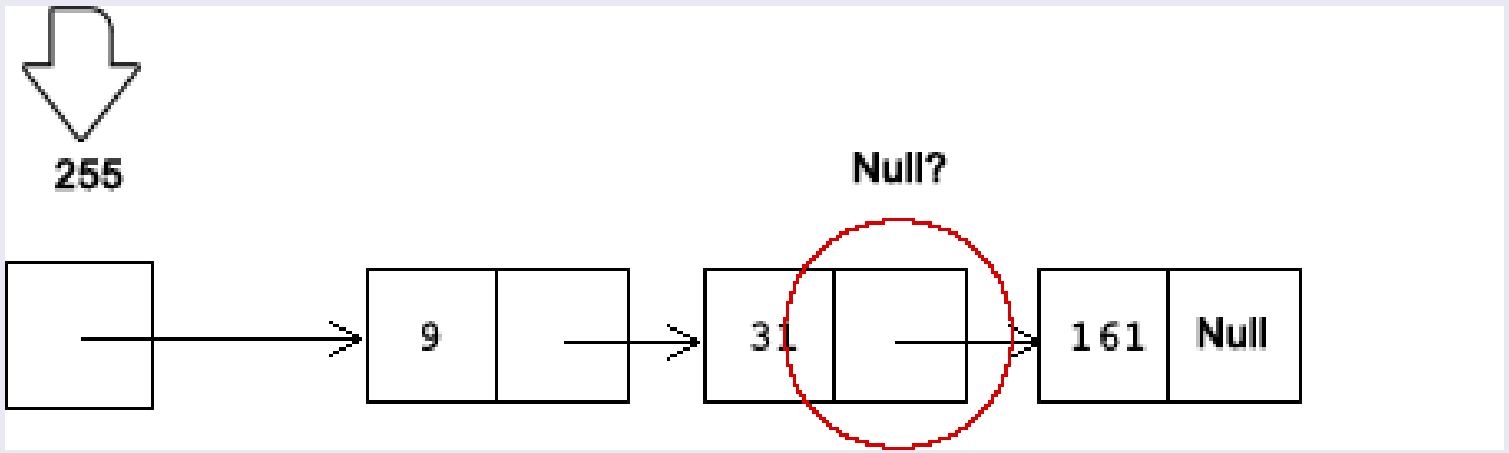

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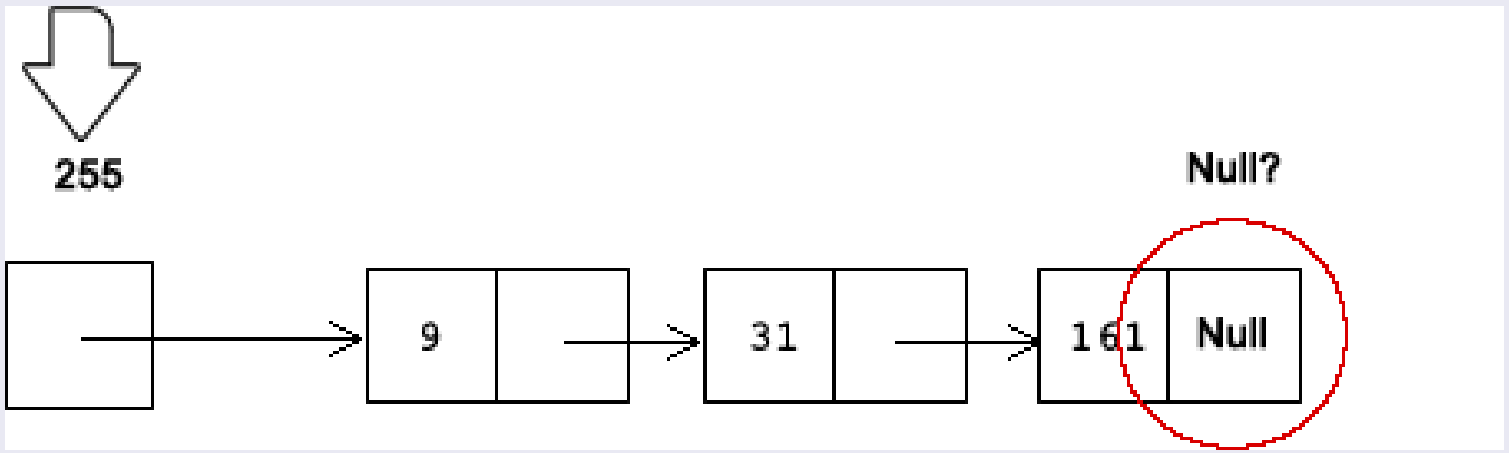

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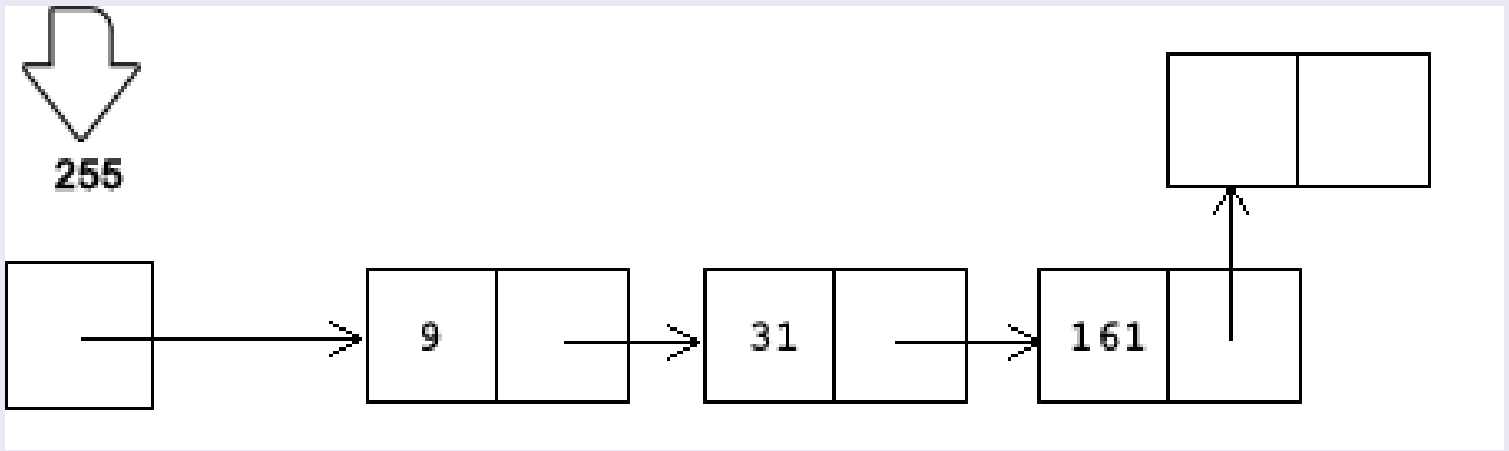
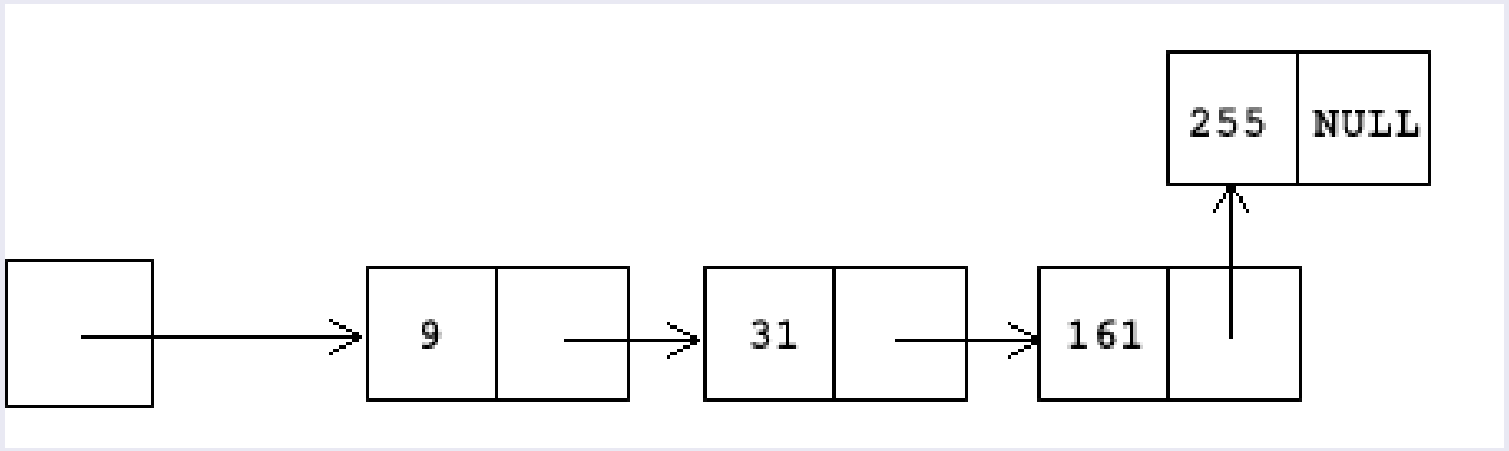


Linked List - Insert

Insert a node - Example



Linked List - Delete

Algorithm

1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be deleted

Linked List - Delete

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1. Let `pointer` a pointer to the head node of the Linked List, and `data` an integer value to be deleted
2. Check if the pointer to the `next` position is null and if the data of the pointer to the next position is what I'm looking for, if so, check the next step, otherwise move the pointer to the `next` reference and keep it searching

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4. If the data has been found in the `next` node, store the reference to the `next` node in a `temp` pointer

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5. Points the `next` field of the current node, to the `next` field of the `temp` node

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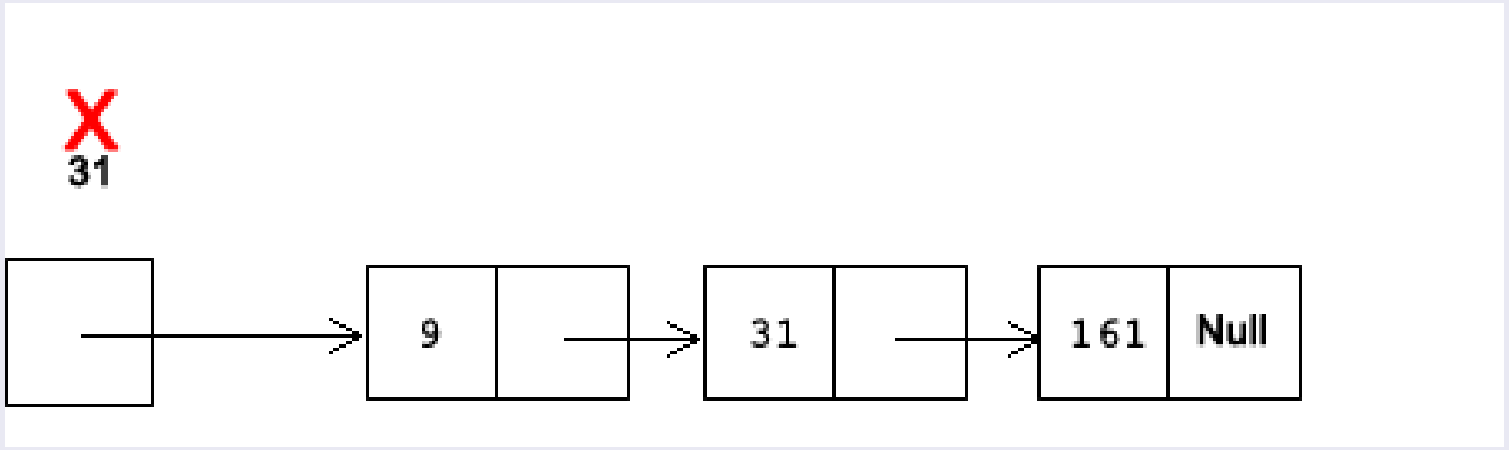
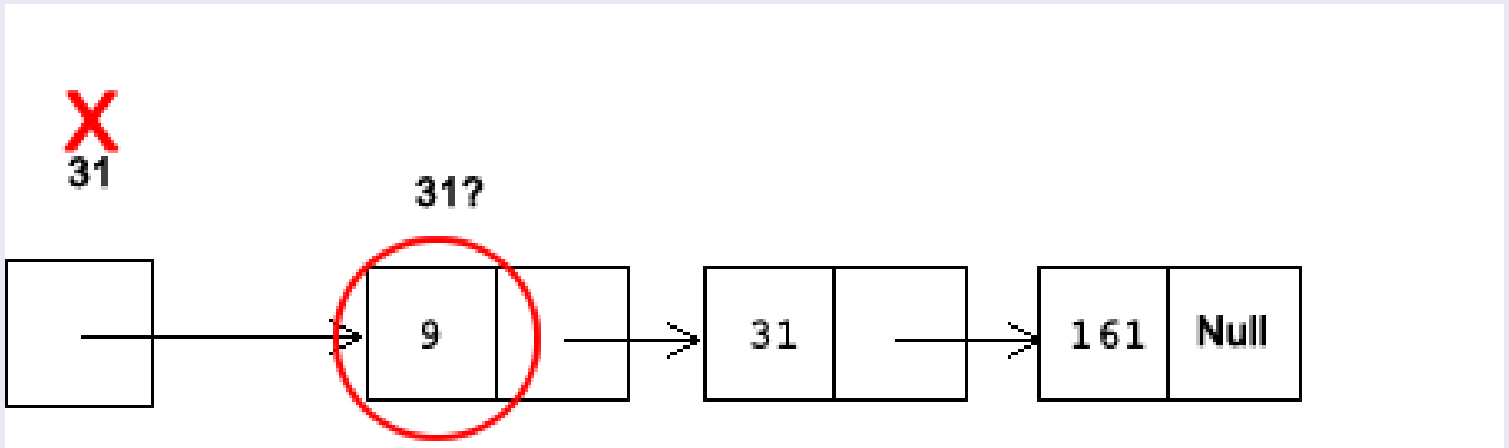
Linked List - Delete

Delete a node - Example



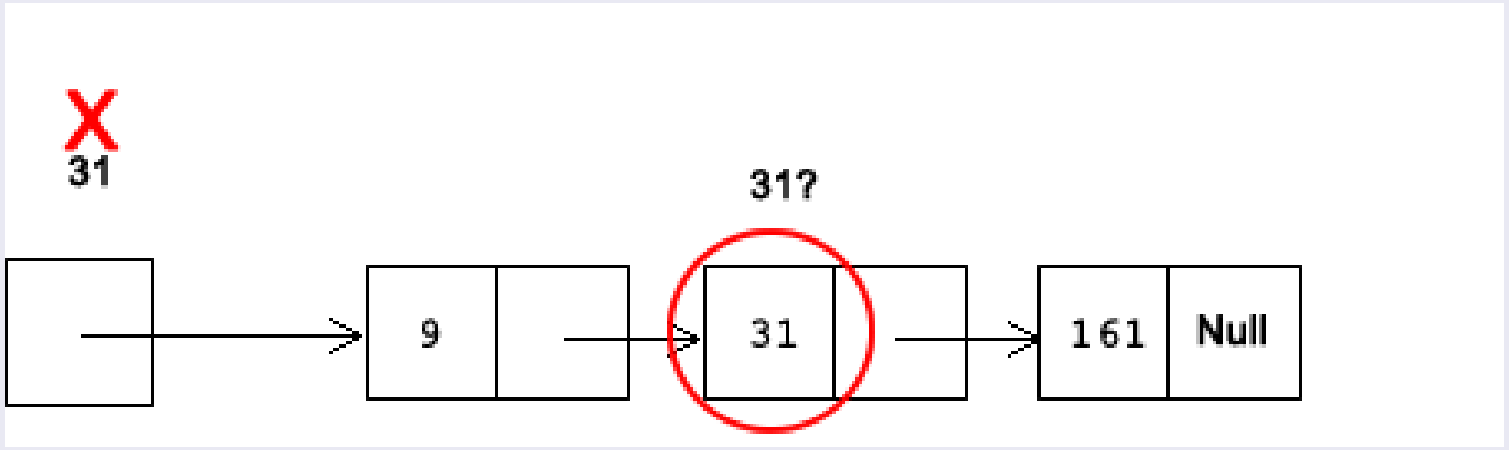
Linked List - Delete

Delete a node - Example



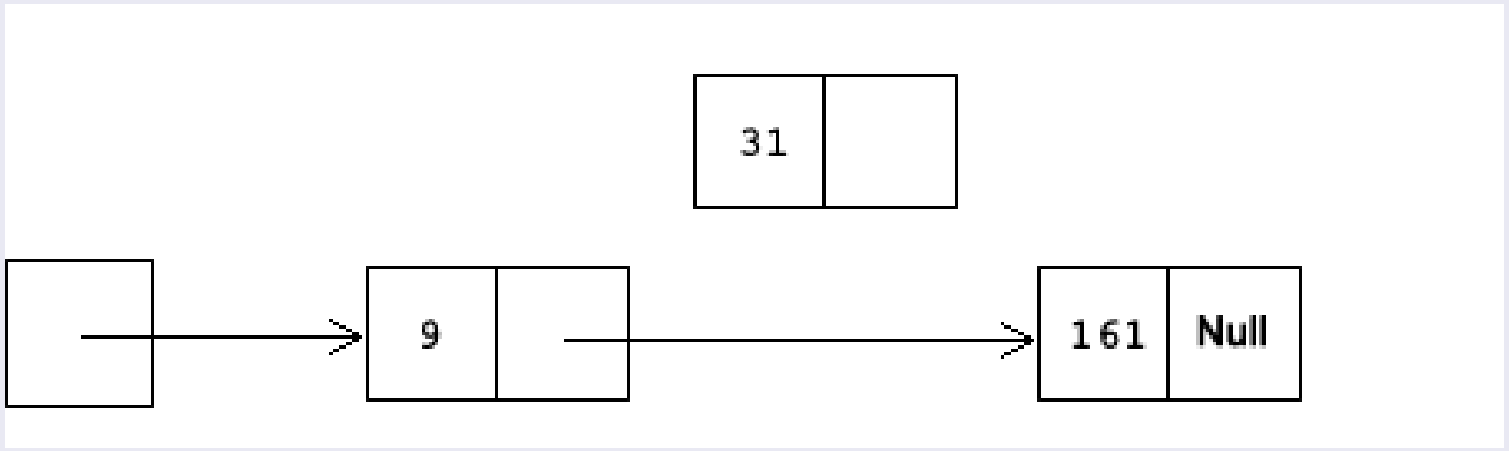
Linked List - Delete

Delete a node - Example



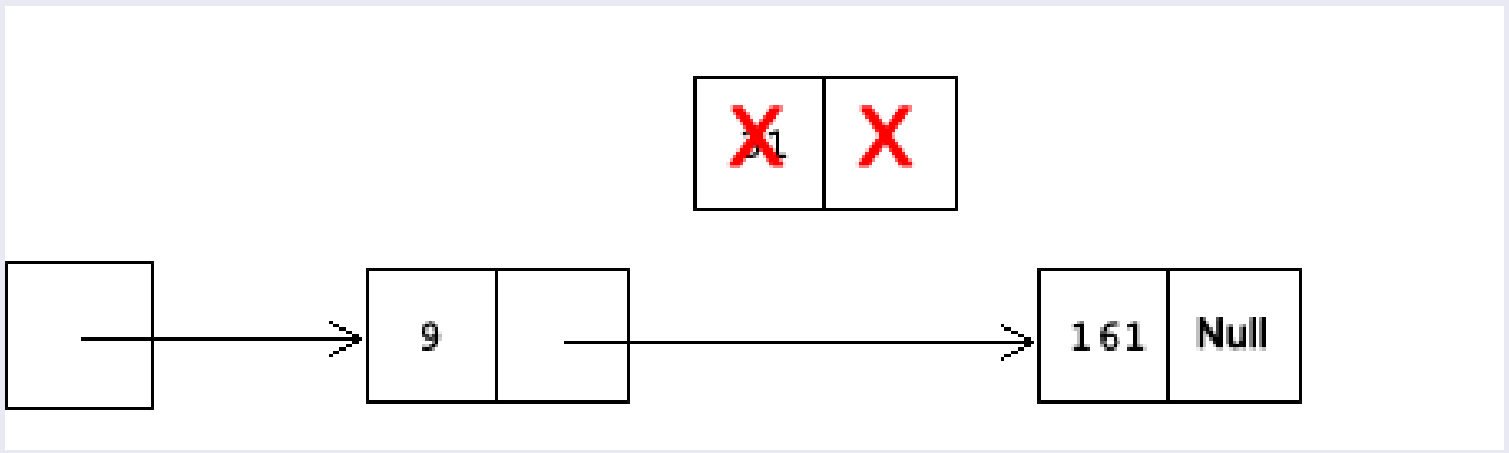
Linked List - Delete

Delete a node - Example



Linked List - Delete

Delete a node - Example



Linked List - Find

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3. If the pointer to the next position is null, the value has not been found so, return 0

Linked List - Find

Algorithm

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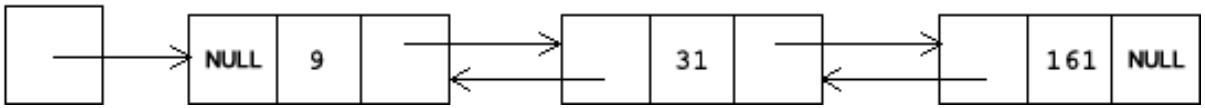
2. Check if the pointer to the `next` position is null and if the data of the pointer to the next position is what I'm looking for, if so, check the next step, otherwise move the pointer to the `next` reference and keep it searching
3. If the pointer to the next position is null, the value has not been found so, return 0
4. If the data has been found in the `next` node, return 1

Outline

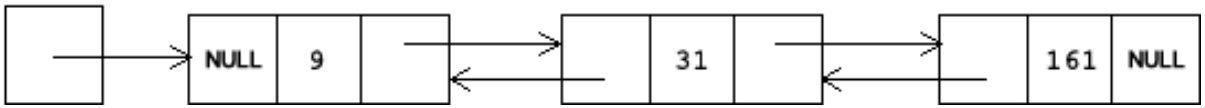
Doubly Linked List



Definition

A Doubly Linked List is a new abstraction of a Linked list where we can traverse the list from back to front

Doubly Linked List



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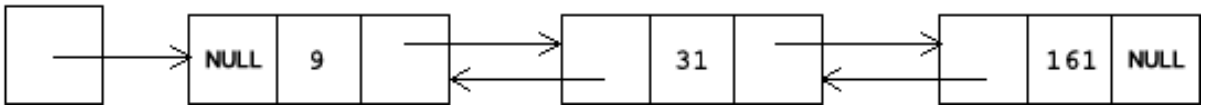
A Doubly Linked List is a new abstraction of a Linked list where we can traverse the list from back to front

- Every *node* of the list contains tree elements:
  - The stored value

Doubly Linked List

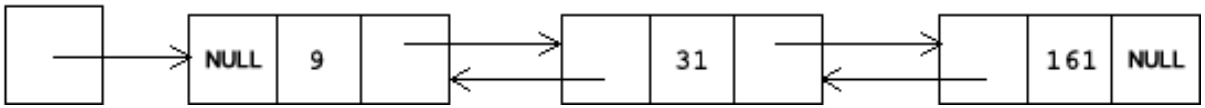


Definition

A Doubly Linked List is a new abstraction of a Linked list where we can traverse the list from back to front

- Every *node* of the list contains tree elements:
  - The stored value
  - A pointer to the next node

Doubly Linked List



Definition

A Doubly Linked List is a new abstraction of a Linked list where we can traverse the list from back to front

- Every *node* of the list contains tree elements:
  - The stored value
  - A pointer to the next node
  - A pointer to the previous node

Linked List

Operations

- `insert`
  Input: A pointer to the linked list and the element to insert
  Do: Inserts the element at the last position of the list

Linked List

Operations

- `insert`
  Input: A pointer to the linked list and the element to insert
  Do: Inserts the element at the last position of the list
- `delete`
  Input: A pointer to the linked list and the element to delete
  Do: Search for the element, and delete the node

Linked List

Operations

- `insert`
  Input: A pointer to the linked list and the element to insert
  Do: Inserts the element at the last position of the list
- `delete`
  Input: A pointer to the linked list and the element to delete
  Do: Search for the element, and delete the node
- `find`
  Input: A pointer to the linked list and the element to search
  Do: Search for the element node per node, and return `1` if the element was found, otherwise `0`