MTH251

Data Structures and Algorithms I

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About Me

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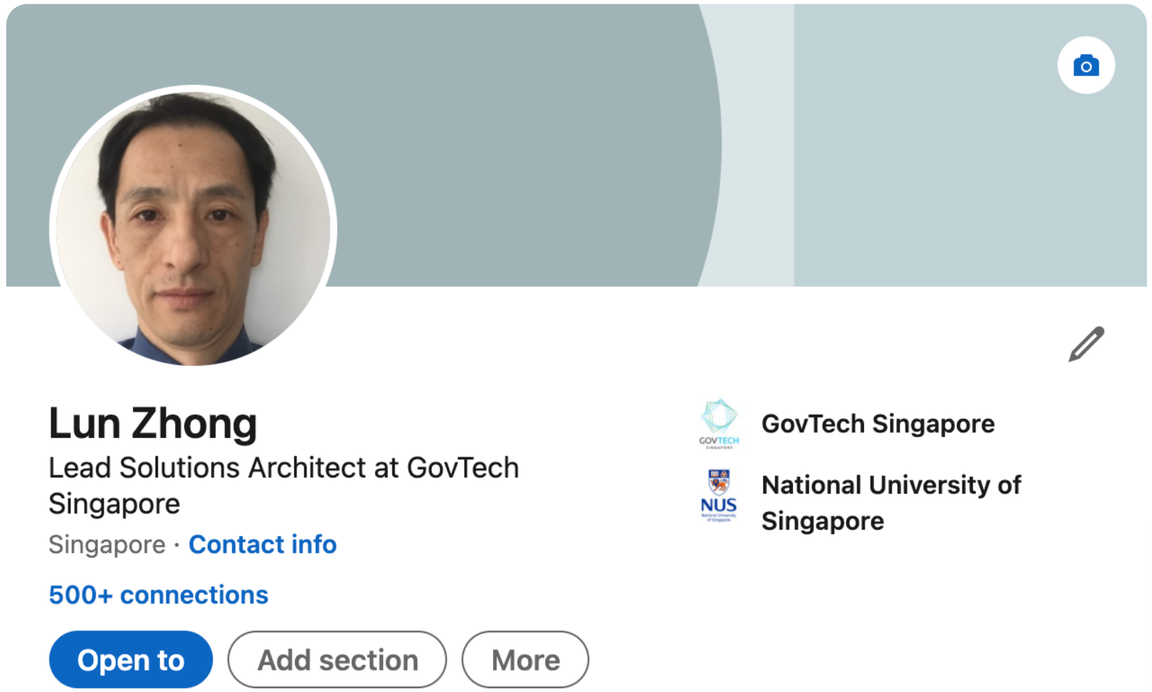


Course Structure

6 weeks (Jan ~ Mar), 6 seminars, 6 labs:

1. Python, Complexity & Big O
2. Array, Stack, Queue
3. Linked List, Recursion, Binary Search
4. Tree
5. Algorithm Design & Pattern
6. Review

3 assignments & open book exam:

Assessment	Description	Weight Allocation
Assignment 1	Tutor-Marked Assignment 1	10%
Assignment 2	Tutor-Marked Assignment 2	10%
Assignment 3	Tutor-Marked Assignment 3	10%
Examination	Open book exam	70%
TOTAL		100%

Learning Objectives

1. python
2. algorithm time & space complexity
3. basic data structure: **array** **stacks** **queues** **list** **tree**
4. recursion algorithm

Learning Resource

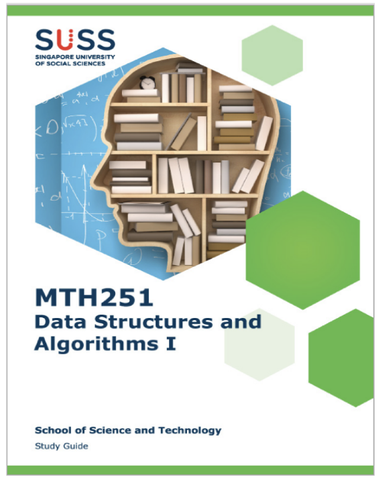
slides online: https://mth251.fastzhong.com/

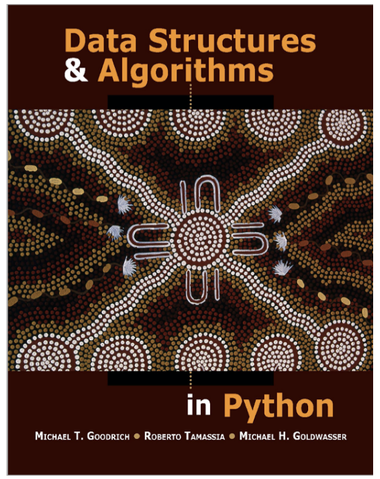
pdf: https://github.com/fastzhong/mth251/blob/main/mth251.pdf

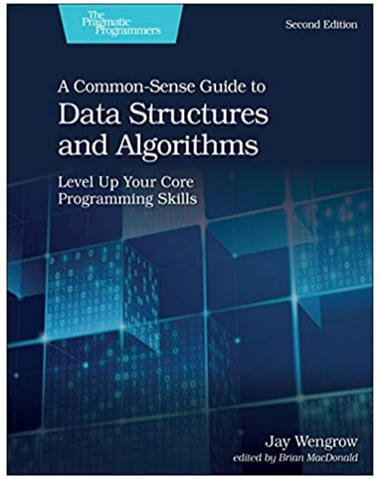
labs: https://github.com/fastzhong/mth251/tree/main/notebooks

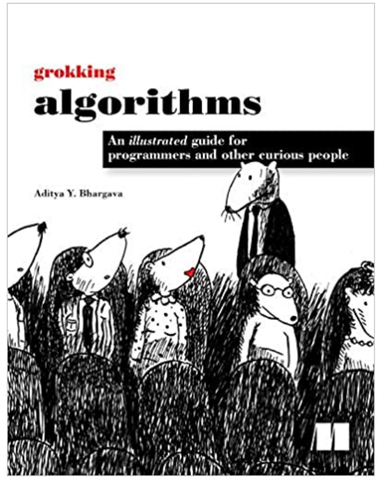
Learning Resource

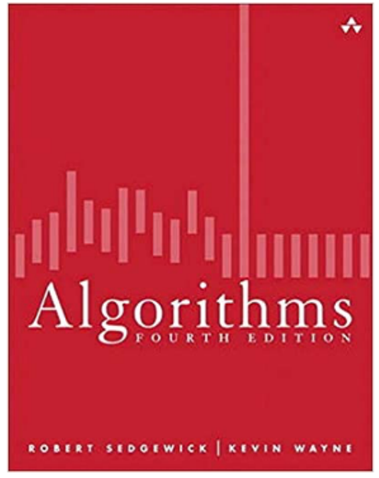
books

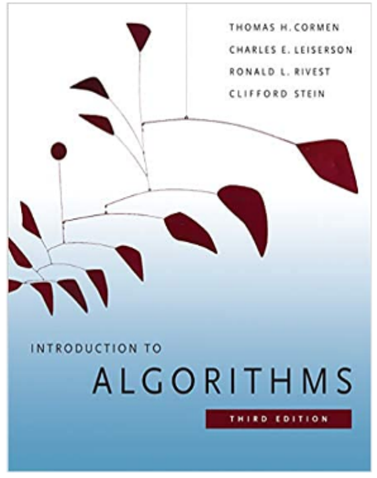






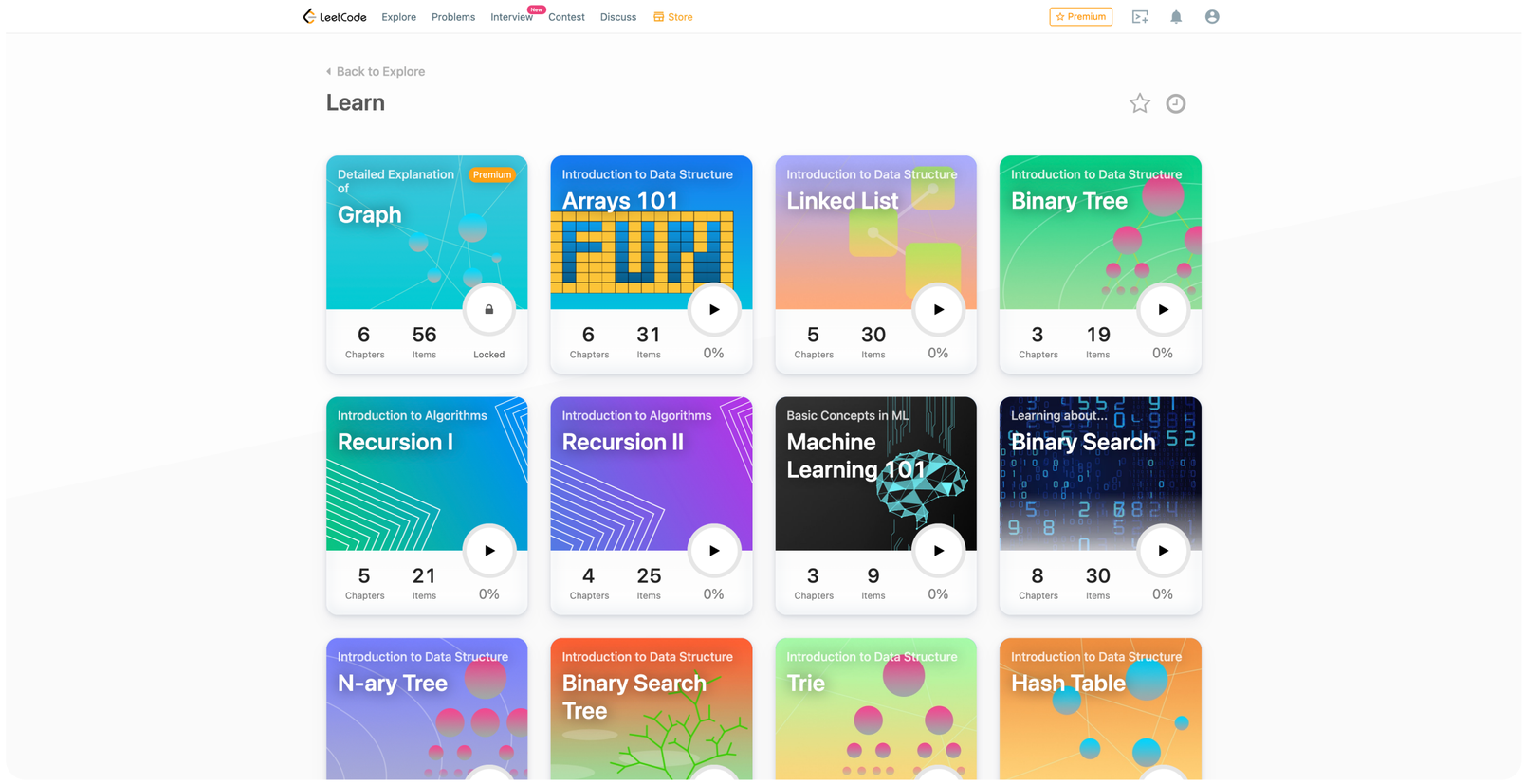






Learning Resource

Leetcode



Why Python

> *The TIOBE Programming Community index is an indicator of the popularity of programming languages.*

Oct 2021	Oct 2020	Change	Programming Language	Ratings	Change
1	3	▲	Python	11.27%	-0.00%
2	1	▼	C	11.16%	-5.79%
3	2	▼	Java	10.46%	-2.11%
4	4		C++	7.50%	+0.57%
5	5		C#	5.26%	+1.10%
6	6		Visual Basic	5.24%	+1.27%
7	7		JavaScript	2.19%	+0.05%
8	10	▲	SQL	2.17%	+0.61%

Why Python

✔ Easy To Learn

✔ Human Readable

✔ Productivity

✔ Cross Platform

> **The Zen of Python, by Tim Peters**
> Beautiful is better than ugly.
> Explicit is better than implicit.
> Simple is better than complex.
> Readability counts.
> Special cases aren’t special enough to break the rules.
> There should be one-- and preferably only one --obvious way to do it.
> If the implementation is hard to explain, it’s a bad idea.

Python Jobs

✔ backend: **Python** vs. Java, C++, Go, Php

✔ devops: **Python** vs. Go, Ruby, Shell

✔ test automation: **Python** vs. Groovy, shell

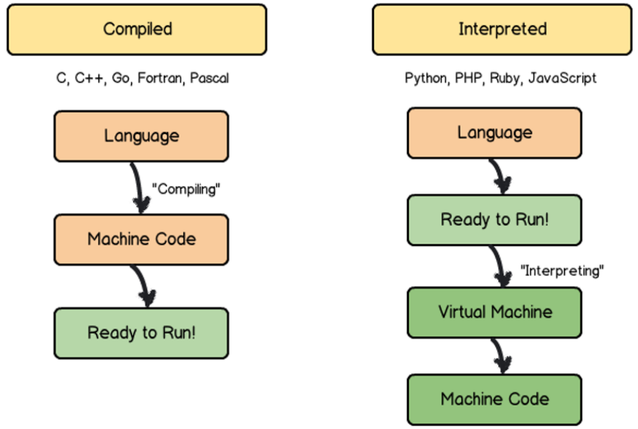
✔ data engineering: **Python** vs. Java, C++

✔ data analytics & visualization: **Python** vs. R, Java, C++

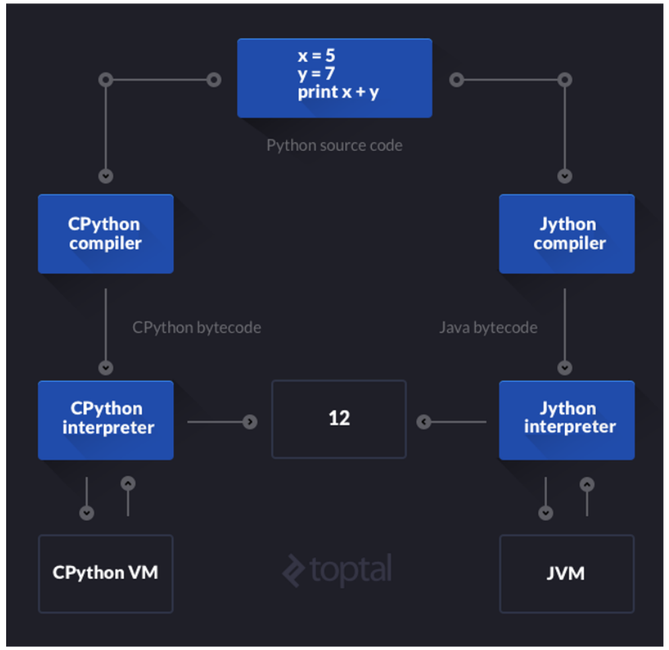
✔ data science & machine learning: **Python** vs. R, Julia, C++

Python 101

- Compiled vs. Interpreted



- CPython bytecode



- Python implementations

Implementation	Virtual Machine	Ex) Compatible Language
CPython	CPython VM	C
Jython	JVM	Java
IronPython	CLR	C#
Brython	Javascript engine (e.g., V8)	JavaScript
RubyPython	Ruby VM	Ruby

Python Data Type & Operators

- numbers: `int` `float` `complex`
  - arithmetic operator: `+` `-` `*` `/` `//` `%` `**`
  - bitwise operator: `&` `|` `^` `>>` `<<` `~`
  - `range()`: a list of integers
- strings: `''` `""` `'` `"` `\t` `\n` `\r` `\\` etc.
  - `join()` `split()` `ljust()` `rjust()` `lower()` `upper()` `lstrip()` `rstrip()` `strip()` etc.
- boolean: `True` `False`
  - True: non-zero number, non-empty string, non-empty list
  - False: 0, 0.0, "", [], None

Python Data Type & Operators

- boolean: `True` `False`
  - logic operator: `and` `or` `not`
  - comparison operator: `>` `<` `>=` `<=` `==` `! =`
  - identity operator: `is` `is not`
- None
- type conversion/casting: `int()` `float()` `str()` `bool()` `hex()` `ord()`

Python Collections

- collections: `list` `tuple` `set` `dictionary`
  - membership operator: `in` `not in`
- list []: a collection of items, usually the items all have the same type
  - sequence type
  - sortable
  - grow and shrink as needed
  - most widely used
- tuple (): a collection which is ordered and unchangeable
- set {}: a collection which is unordered and unindexed

Python Program Structure

- variable
- statement & comments
  - Python uses new lines to complete a command, as opposed to other programming languages often use `;` or `()`; relies on indentation (whitespace sensitive), to define scope, such as the scope of loops, functions and classes, as opossed to other programming languages often use `{}`
- control flow
  - `if … elif … else`
  - `while` `for` `break` `continue`

Python Program Structure

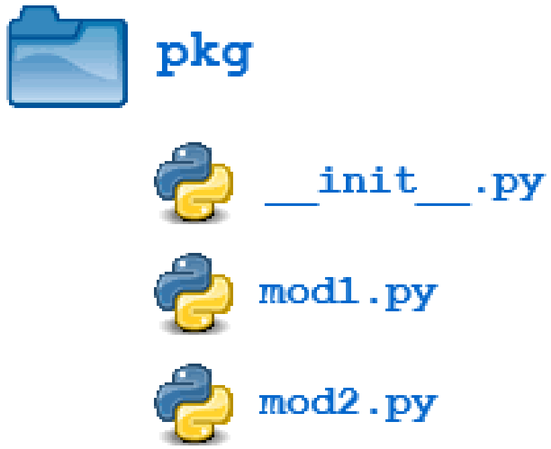
- function
  - `def` `return`
  - `__main__`
  - advanced:
    - lambda
    - decorator
    - closure
- error/exception
  - handling exception: `try … except … else … finally`
  - raise execption: `raise`

Python OO & Class

- `Procedural` vs. `OOP` vs. `FP`
- OO Principal
  - `Inherience`
  - `Encapsulation`
  - `Polymorphism`
- class, instance, attributes, properties, method
- `override` vs. `overload` vs. `overwrite`

Misc.

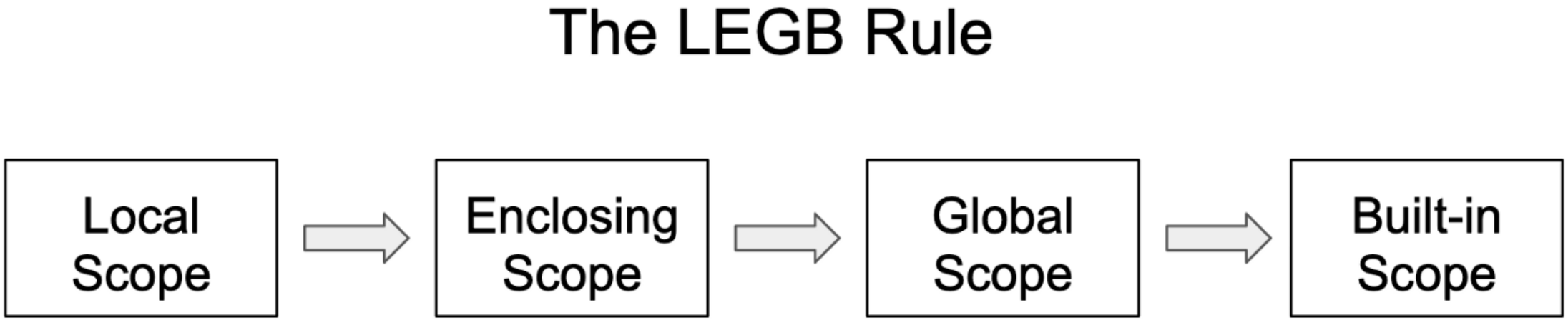
- modular programming: `function` → `class` → `module` → `package`
- Modules: Python module (default main module), C module, Build-in module
- Packages:



- Standard Lib: `math` `random` `re` `os` `itertools` `collections`

Misc.

- Namespaces & Scopes: `LEGB` rule



- help

Python Tutorials

Programming with Mosh

- Python Tutorial - Python for Beginners 2020

freeCodeCamp

- Learn Python - Full Course for Beginners Tutorial
- Python for Everybody - Full University Python Course
- Intermediate Python Programming Course

Tech With Tim

- Learn Python - Full Course for Beginners Tutorial

Cheatsheet:

- 
Python Crash Course - Cheat Sheets
- 
Comprehensive Python Cheatsheet

Data Structure & Algorithms

A data structure is a way of organizing information so that it can be used effectively by computer

Algorithms provides computer step by step instructions to process the information and solve a problem

Program = Data Structure + Algorithm

- Finiteness
- Definiteness
- Effectiveness
- Input
- Output

Data Structure & Algorithms

Example1:

Data Structure & Algorithms

Example2:

Data Structure & Algorithms

Data Structure

- Linear
  - Array, String, Linked List
  - Stack, Queue, Deque, Set, Map/Hash, etc.
- Non-Linear
  - Tree, Graph
  - Binary Search Tree, Red-Black Tree, AVL, Heap, Disjoin Set, Trie, etc.
- Others
  - Bitwise, BloomFilter, LRU Cache

Algorithms & Data Structure

Algorithms

- branching: if-else, switch
- iteration: for, while loop
- recursion: divide & conquer, backtrace
- searching: binary search, depth first, breath first, A*, etc.
- sorting: quick sort, bubble sort, merge sort, etc.
- dynamic programming
- greedy
- ...

Algorithms & Data Structure

Why

✓ deeper understanding of computer system

✓ improve coding skill

✓ coding interview

✓ building framework and library

How

🤹 learning by doing, implementing from scratch

🤦 problem solving

Algorithm Complexity Analysis

Performance

- cpu, memory, io, networking, etc.
- worst case, avg case, best case
- data.size()
- no. of lines
- ...

Algorithm Complexity Analysis

- **Time Complexity** : by giving the size of the data set as integer N, consider the number of operations that need to be conducted by computer before the algorithm can finish
- **Space Complexity** : by giving the size of the data set as integer N, consider the size of extra space that need to be allocated by computer before the algorithm can finish
- When: Accessing, Searching, Inserting, Deleting

Big-O

> *Big-O describes the trend of algorithm performance when the data size increases*

$O(1)$:	constant complexity
$O(\log_* n)$:	logarithmic complexity
$O(n)$:	constant complexity
$O(n^2)$:	N square complexity
$O(2^n)$:	exponential complexity
$O(n!)$:	factorial

Big-O

👉 Master theorem (analysis of algorithms)

$O(f) = f$

$O(c \cdot f) = O(f)$

$O(f + g) = O(max(f, g))$

$O(f) \cdot O(g) = O(f \cdot g)$

$O(f \cdot g) \leq O(f \cdot h)$ if & only if $O(g) \leq O(h)$

$O(x^a) \leq O(x^b)$ if & only if $a \leq b$

$O(a^x) < O(b^x)$ if & only if if $a < b$

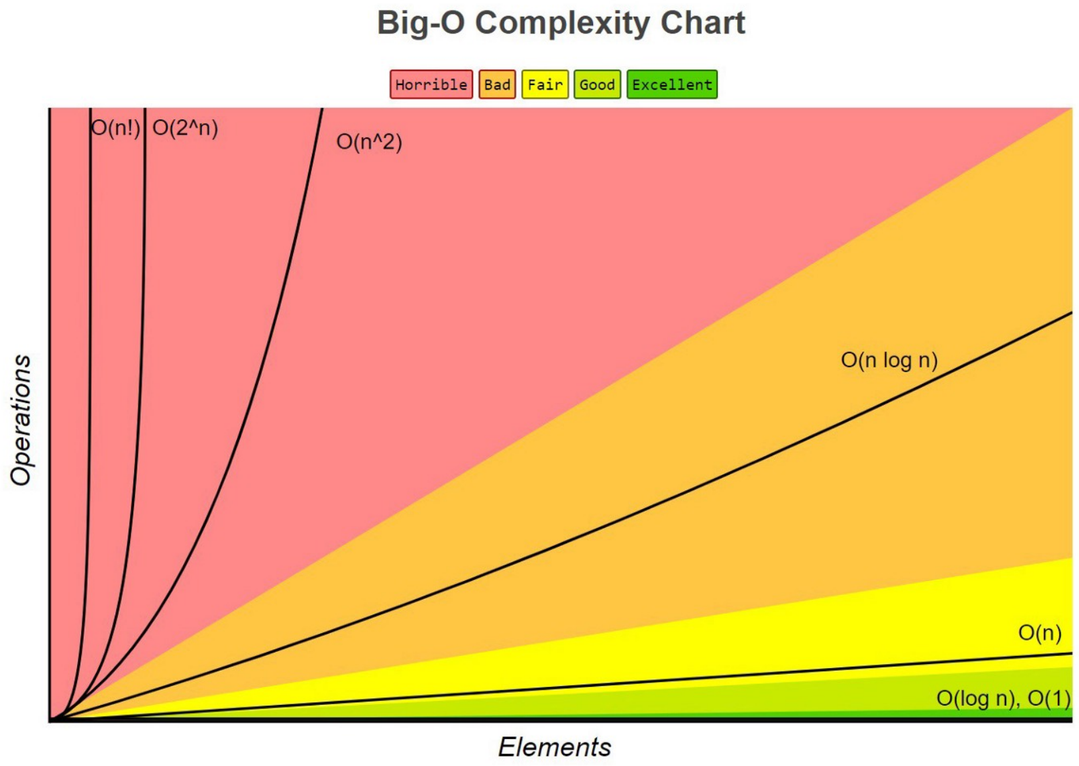
$O(x^a) < O(b^x)$ if & only if if $d > 1$ (assuming $c \geq 1$ and $d \geq 1$)

$O(log_* x) < O(x^c)$ if & only if if $c > 0$

Big-O

https://www.bigocheatsheet.com/

$$O(1) < O(\log_* n) < O(n) < O(n \log_* n) < O(n^2) < O(2^n) < O(n!)$$



Array

To store a list of similar things, example:

A list of names: [“Alex”, “Bob”, “Charles”, “David”]
A list of numbers: [1, 2, 3, 4]

Each item in the array referred as “**element**”

Array

- Element Type: same type (array is structured data)
- Element Size: fixed

```
# java
String[] cars = {“BMW”, “Toyota”, “Tesla”} // declare & init

Integer[] scores = new Integer[10] // declare
// init
scores[0] = 90
scores[1] = 80
```

- Element Index: 0, 1, ..., length - 1

Array 2-D

```
students = [
    [“Alex”,  “M”, “S1111111A”],
    [“Bob”,   “M”, “S2222222B”],
    [“James”, “M”, “S3333333C”],
]
```

students[2] → [“James”, “M”, “S3333333C”]
Students[1][2] → “S2222222B”

Index	0	1	2
0	Alex	M	S1111111A
1	Bob	M	S2222222B
2	James	M	S3333333C

Array Address

str = "HELLO" = ['H', 'E', 'L', 'L', 'O']

Memory Address	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	...
Computer's memory	H		E		L		L		O		...
Index Number	0		1		2		3		4		

data type: char

data type size: 2 byte (1 byte = 8 bits, 0000 0000 ~ 1111 1111)

total_size = array_size * data_type_size

array[i].address = base_address + i * data_type_size

👉 O(1)

Array Operations

Operation	Array	Dynamic Array
Accessing	O(1)	O(1)
Searching	O(n)	O(1)
Inserting	-	O(n)
Deleting	-	O(n)

ADT vs. Data Structure

An **abstract data type** (ADT) is an abstraction of a **data structure** which provides only the interface to which a data structure must adhere to. The interface does not give any specific details about how something should be implemented.

Programming language provides different **data types** to implement/represent different data structure.

i.e. Array

- a linear abstract data type
- a java data type

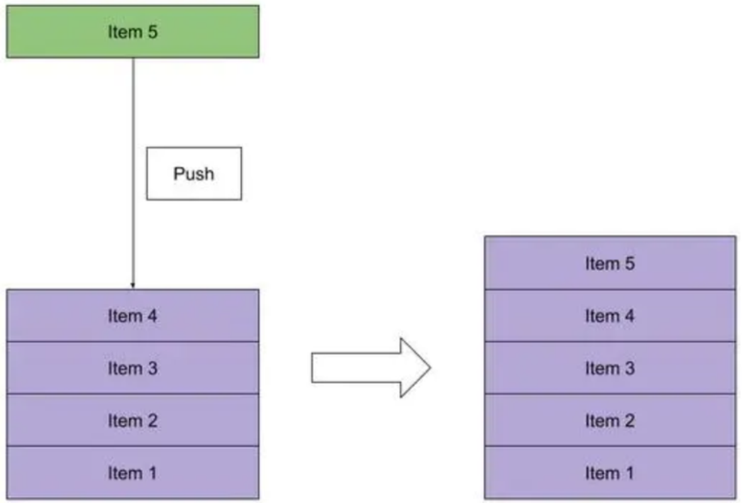
Dynamic Array

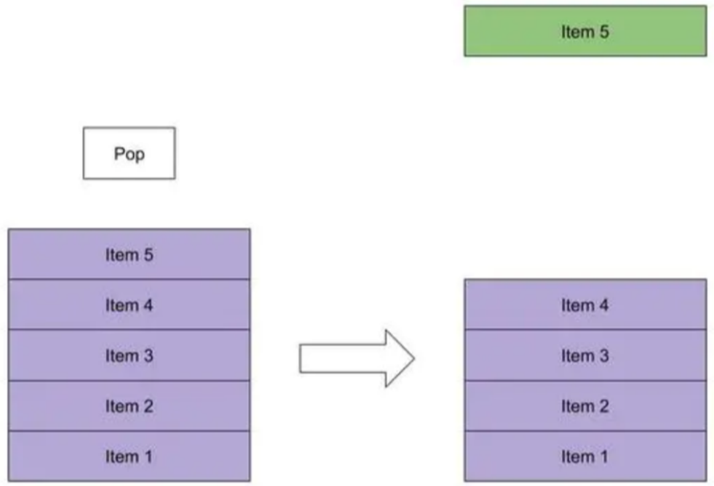
Stack

- Sequential Access vs Random Access (such as Array)
- **LIFO** (Last In First Out) sequential collection

Stack: Operations

- **push**() – pushing (storing) an element on the stack
- **pop**() – removing (accessing) an element from the stack
- top()/peek() – get the top data element of the stack, without removing it
- size(), isEmpty(), isFull()





Stack Operations

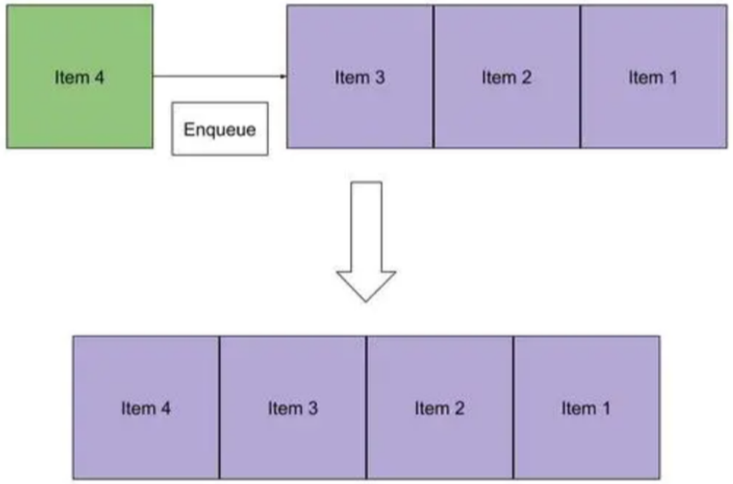
Operation	Stack
Accessing	O(n)
Searching	O(n)
Inserting	O(1)(push)
Deleting	O(1)(pop)

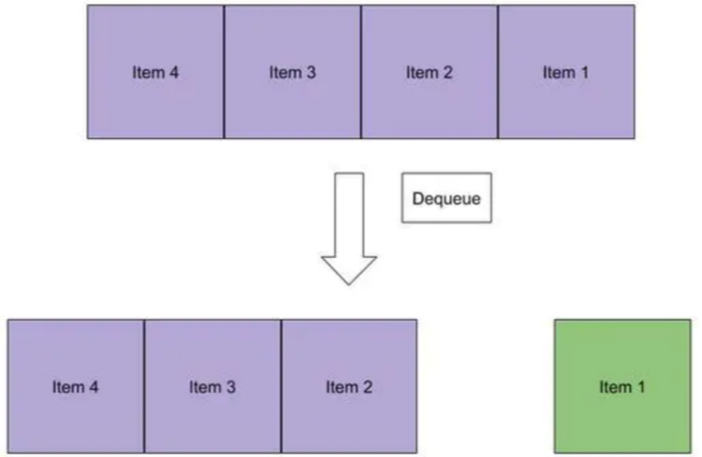
Queue

- **FIFO** (First In First Out) sequential collection

Queue: Operations

- **enqueue**() – adding (storing) an element to the queue
- **dequeue**() – removing (accessing) an element from the queue
- fist()/peek() – get the first element of the queue, without removing it
- size(), isEmpty(), isFull()





Queue Operations

Operation	Queue
Accessing	O(n)
Searching	O(n)
Inserting	O(1)(enqueue)
Deleting	O(1)(dequeue)

Linked List

- dynamic linear data structure
- data stored in a “Node” class
- data & pointer

code here

Linked List Operations

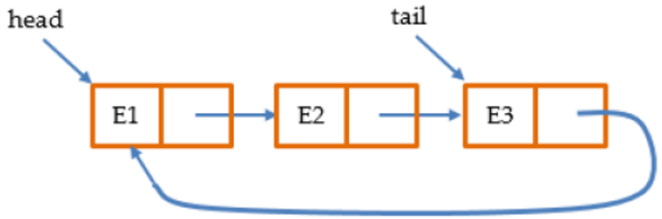
Operation	Linked List	Dynamic Array
Accessing	O(n)	O(1)
Searching	O(n)	O(n)
Inserting	O(1)	O(n)
Deleting	O(1)	O(n)

Linked List

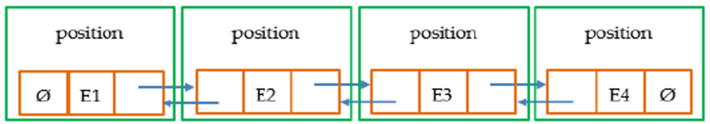
Singly Linked List

Doubly Linked List

Circular Linked List



Positional Linked List



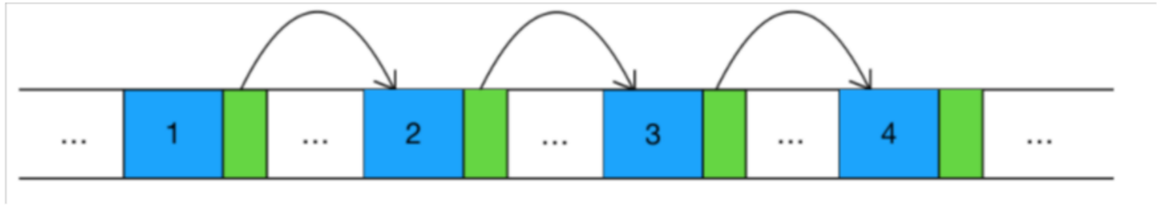
Linked List vs. Array

✔ dynamic, no need to deal with fixed memory size
✖ accessing speed

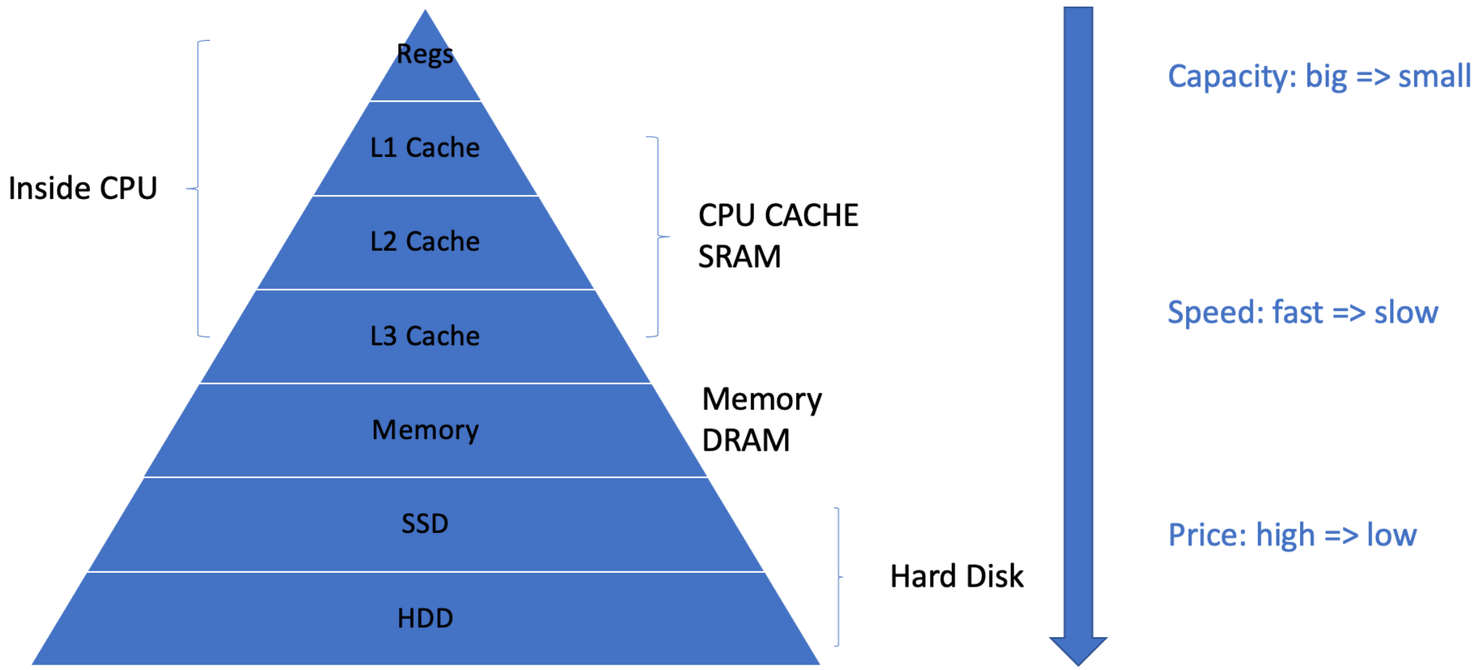
Array:

Memory Address	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	...
Computer's memory	H		E		L		L		O		...
Index Number	0		1		2		3		4		

Linked List:



Linked List vs. Array



Recursion

Recursion by definition is a function that calls itself.

- base case
- recursive case

Example:

Fibonacci sequence 0, 1, 1, 2, 3, 5, 8, ...

- when n = 1, fib(1) = 0
- when n = 2, fib(2) = 1
- when n > 2, fib(n) = fib(n-1) + fib(n-2)

```
def fib_recursive(n):
    if (n == 1):
        return 0
    if (n == 2):
        return 1
    return fib_recursive(n-1) + fib_recursive(n-2)
```

base case

recursive case

Recursion vs. Iterative

> *Anything with a recursion can be done iteratively (loop)*

🤗 Intuitive/DRY, code readability

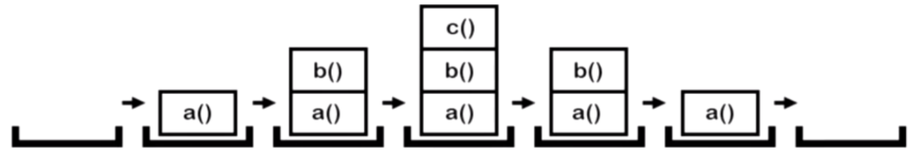
```python
def fib_recursive(n):
    if (n == 1):
        return 0
    if (n == 2):
        return 1
    return fib_recursive(n-1) + fib_recursive(n-2)
```


🤔 Optimization, call stack

```python
def fib_iterative(n):
    fib = [0,1]
    i = 2
    while (i < n): # index: 2, 3, ..., n-1
        fib.append(fib[i-1] + fib[i-2]) # fib[i]
        i += 1
    return fib[n-1] # the nth number
```

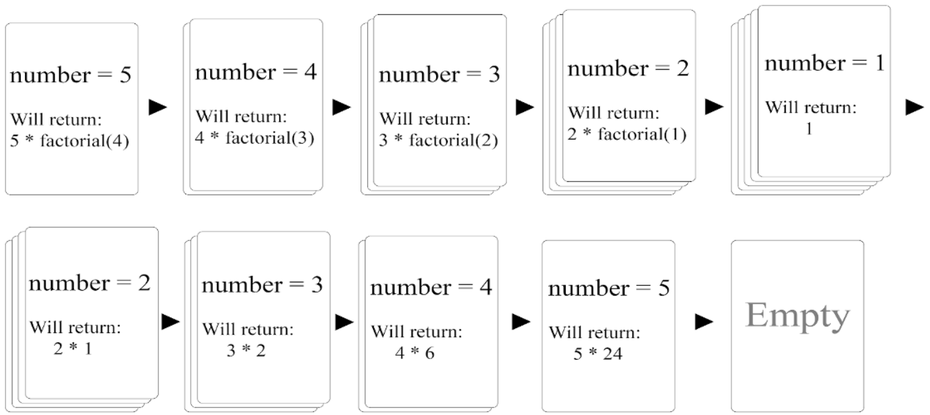
Recursive Call

Call Stack:



The “call stack” is a stack of “frame objects”.
(frame object == a function call)

fib_recursive(5):



Recursive Call

- Max call stack size (stack overflow error)
- Tail Call Optimization
- Memorization

Recursive Call

Fundamental technique to solve problem:

- Identifying the base case
- Identifying the recursion formula/equation to transform the problem to smaller version
  - Problem requires back-tracking
  - Problem has tree structure

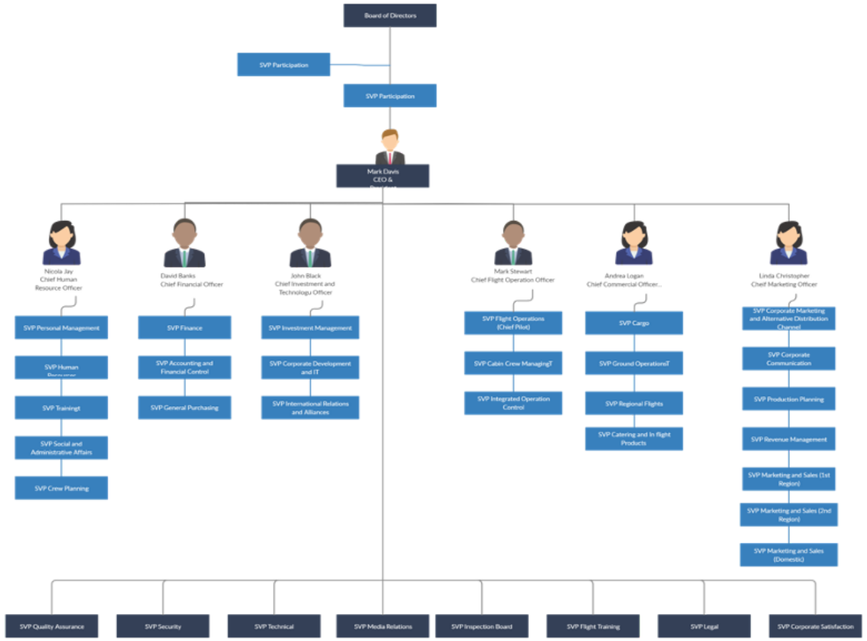
Linear Search

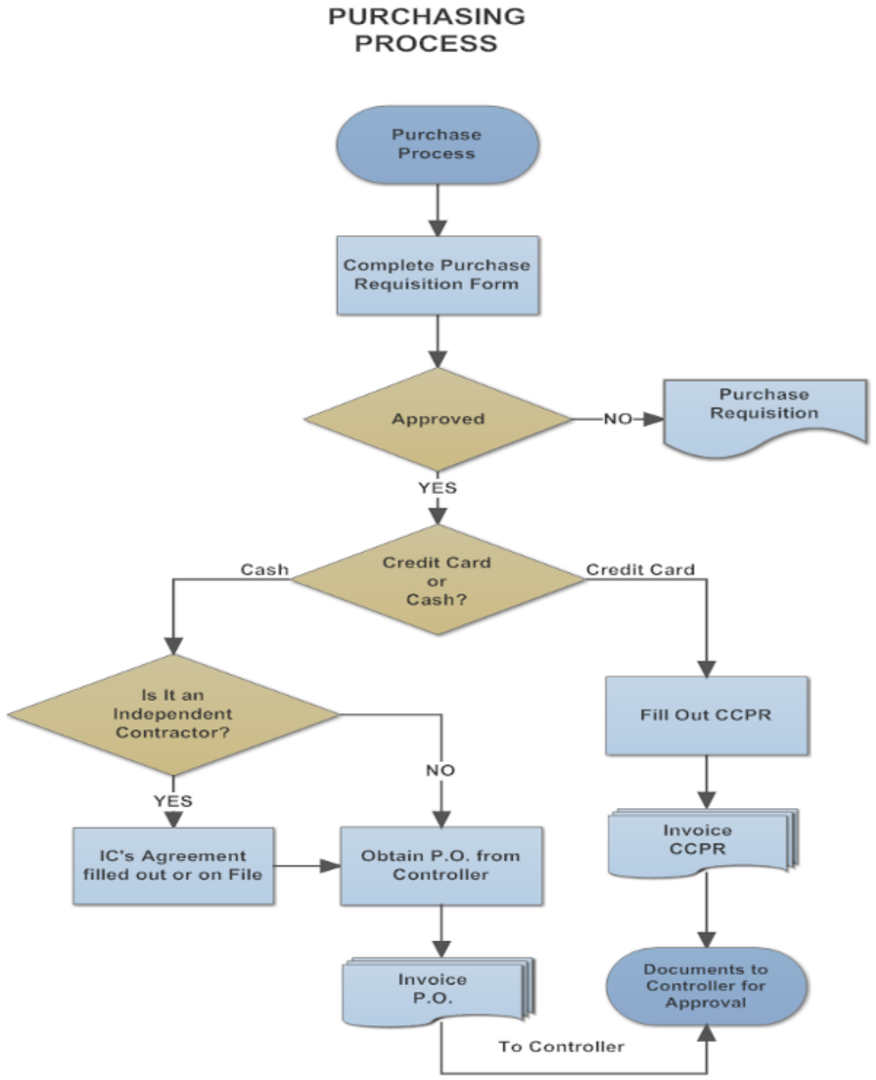
- Input: array, target element
- Output: position (-1 if not existing)

Binary Search

- Input: array, target element
- Output: position (-1 if not existing)

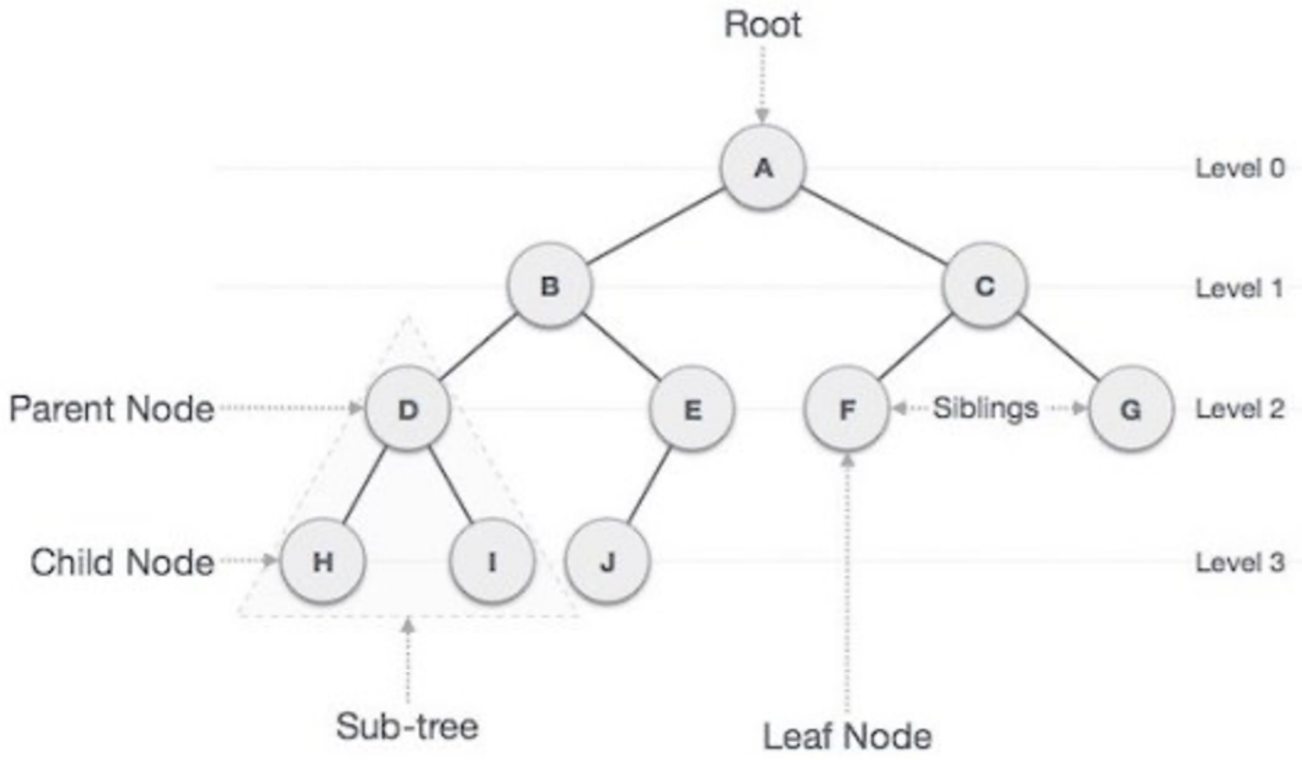
Tree


Board of Directors
SVP Participation
SVP Participation
Mark Davis
CEO &
Nicola Jay
Chief Human
Resource Officer
David Banks
Chief Financial Officer
John Black
Chief Investment and
Technology Officer
Mark Stewart
Chief Flight Operation Officer
Andrea Logan
Chief Commercial Officer...
Linda Christopher
Chief Marketing Officer
SVP Personal Management
SVP Human
SVP Trainingt
SVP Social and
Administrative Affairs
SVP Crew Planning
SVP Finance
SVP Accounting and
Financial Control
SVP General Purchasing
SVP Investment Management
SVP Corporate Development
and IT
SVP International Relations
and Alliances
SVP Flight Operations
(Chief Pilot)
SVP Cabin Crew ManagingT
SVP Integrated Operation
Control
SVP Cargo
SVP Ground OperationsT
SVP Regional Flights
SVP Catering and in flight
Products
SVP Corporate Marketing
and Alternative Distribution
Channel
SVP Corporate
Communication
SVP Production Planning
SVP Revenue Management
SVP Marketing and Sales (1st
Region)
SVP Marketing and Sales (2nd
Region)
SVP Marketing and Sales
(Domestic)
SVP Quality Assurance
SVP Security
SVP Technical
SVP Media Relations
SVP Inspection Board
SVP Flight Training
SVP Legal
SVP Corporate Satisfaction


PURCHASING
PROCESS
Purchase
Process
Complete Purchase
Requisition Form
Approved
NO
Purchase
Requisition
YES
Credit Card
or
Cash?
Cash
Credit Card
Is It an
Independent
Contractor?
YES
NO
IC's Agreement
filled out or on File
Obtain P.O. from
Controller
Fill Out CCPR
Invoice
CCPR
Invoice
P.O.
Documents to
Controller for
Approval
To Controller

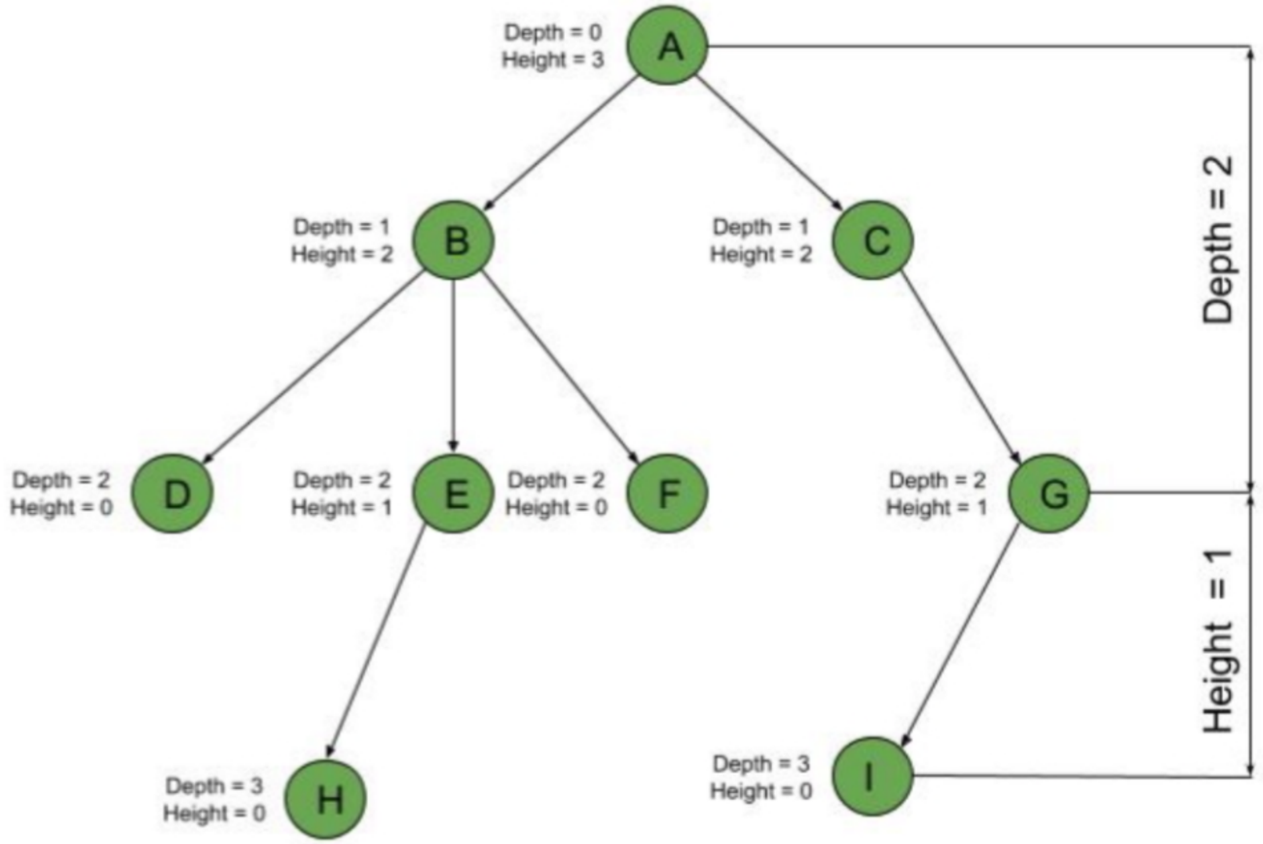
Tree Terminology

- Node: Root, leaf, Internal Node
- Paren, Children, Sibling
- Edge, Degree
- SubTree
- Path
- Level



Tree Terminology

- Level vs. Depth vs. Height

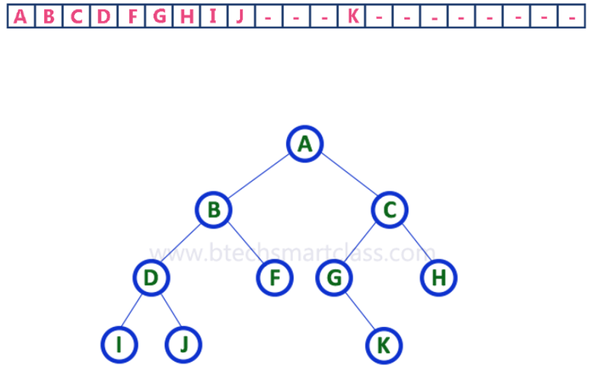


Binary Tree

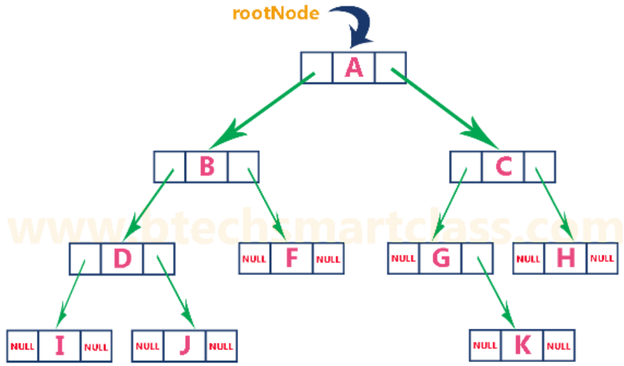
- One one root
- Max 2 child nodes
- One and only one path from root to each node
- Max nodes on level: 2^l
- Max nodes total: $2^{h+1} - 1$

Binary Tree

- Array



- Left/Right Linked List

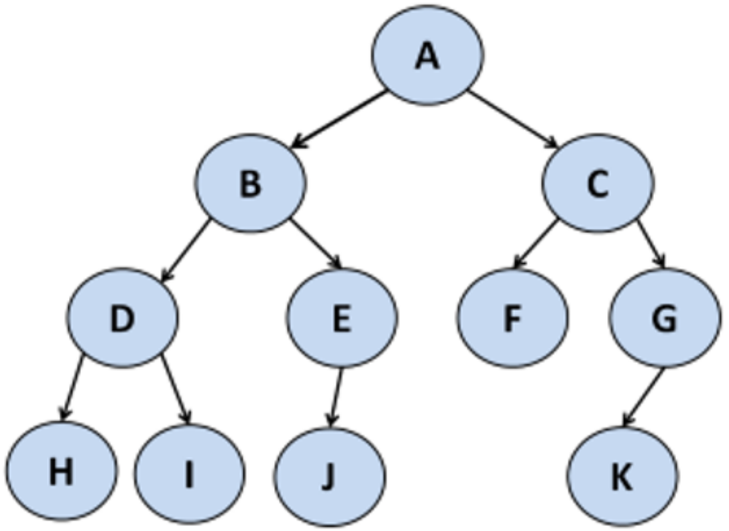


Binary Tree Traverse (DFS): pre-order

ROOT → Left → Right:

1. Visit the root
2. Traverse the left subtree
3. Traverse the right subtree

A B D H I E J C F G K

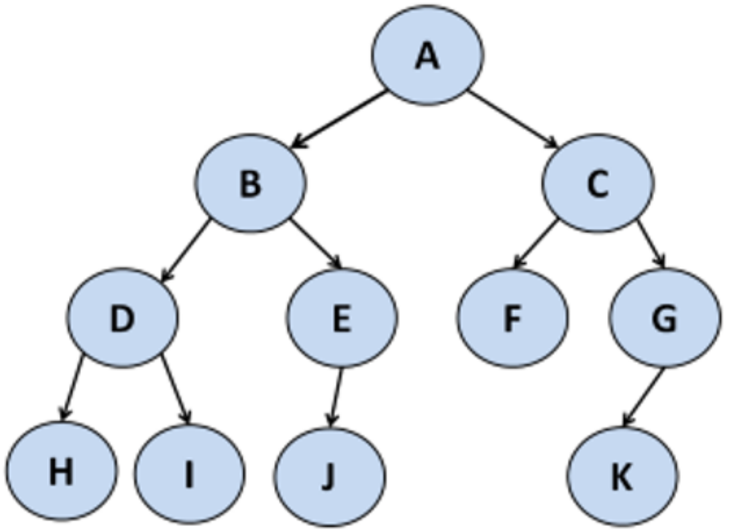


Binary Tree Traverse (DFS): in-order

Left → Root → Right:

1. Traverse the left subtree
2. Visit the root
3. Traverse the right subtree

H D I B J E A F C K G

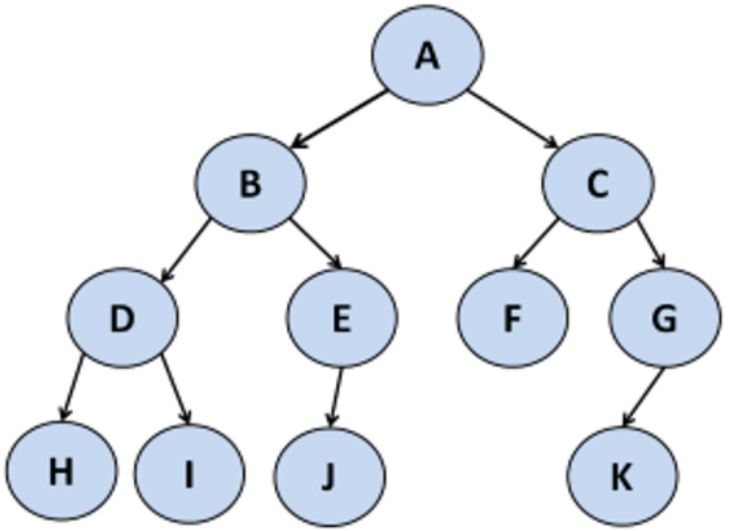


Binary Tree Traverse (DFS): post-order

Left → Right → Root:

1. Traverse the left subtree
2. Traverse the right subtree
3. Visit the root

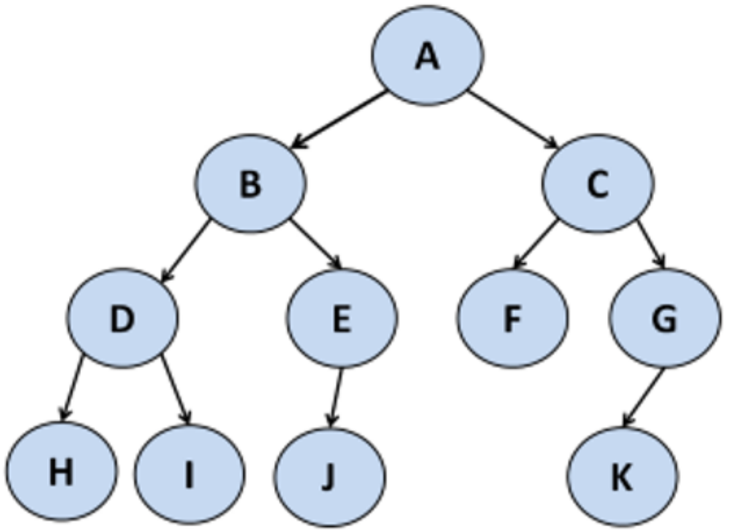
H I D J E B F K G C A



Binary Tree Traverse (BFS): level order

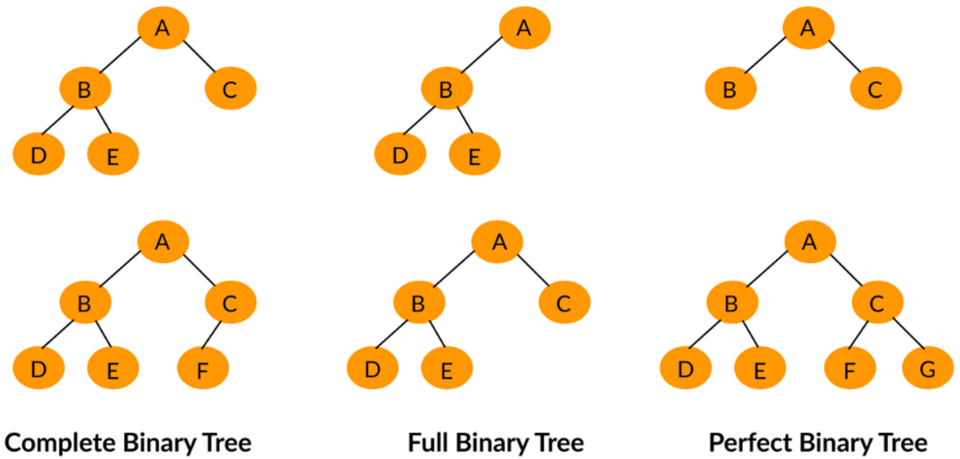
1. Visit the root
2. Visit the left node
3. Visit the right node
4. Go to next level

A B C D E F G H I J K

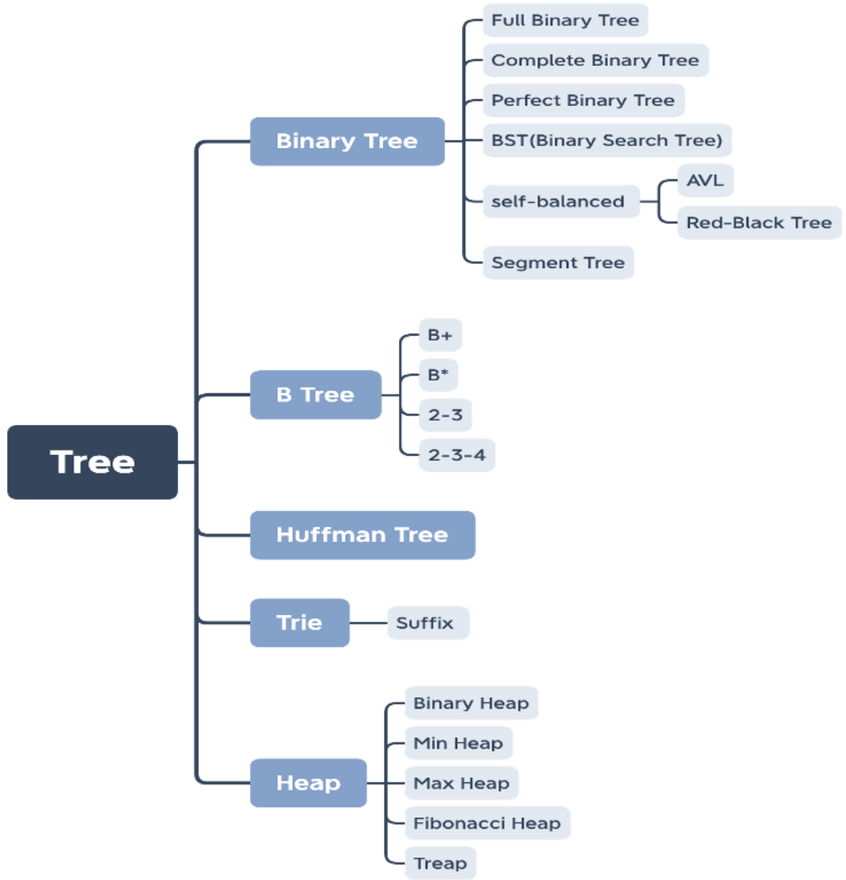


Binary Tree

- Complete Tree: every level is completely filled except the last (leaf) and all nodes are as far left as possible
- Full Binary Tree: every node has two child nodes except leaf
- Perfect Binary Tree: every node has two child nodes except leaf and all leaves on same level



Trees


Tree
Binary Tree
Full Binary Tree
Complete Binary Tree
Perfect Binary Tree
BST(Binary Search Tree)
self-balanced
AVL
Red-Black Tree
Segment Tree
B Tree
B+
B*
2-3
2-3-4
Huffman Tree
Trie
Suffix
Heap
Binary Heap
Min Heap
Max Heap
Fibonacci Heap
Treap

layout: center

Summary

Array

Concept	▪ consecutive memory space: arr[i].address = base_address + i * data_type_size ▪ same data type → same size for each element ▪ fixed length
Operations	**Accessing O(1)**, Searching O(n)
Notes	▪ not memory friendly ▪ cpu cacheable ▪ index from 0 ▪ fundamental data structure to implement others such as stack, queue, heap ▪ data type (programming language) vs. data structure
Hands-on	dynamic array, stack/queue, binary search, etc.

Stack

Concept	**LIFO/FILO**
Operations	Accessing O(n), Searching O(n), Inserting/push O(1), Deleting/pop O(1)
Notes	Stack implementation by dynamic array or linked list
Hands-on	function call stack, expression matching, etc.

Queue

Concept	**FIFO/LILO**
Operations	Accessing O(n), Searching O(n), Inserting/enqueue O(1), Deleting/dequeue O(1)
Notes	Queue implementation by dynamic array or linked list
Hands-on	priority queue, circular queue, job queue, resource pool, etc.

Linked List

Concept	▪ nonconsecutive memory space ▪ node: data + pointer ▪ Single Linked List, Doubly Linked List, Circular Linked List, Positional Linked List
Operations	Accessing O(n), Searching O(n), **Inserting O(1)**, **Deleting O(1)**
Notes	▪ accessing slower than array ▪ with/without head/tail node (which don’t store any data) ▪ fundamental data structure to implement others such as skip list, hash table, etc.
Hands-on	stack, queue, traverse/reverse/update/merge, etc.

Binary Tree

Concept	▪ one root ▪ max 2 child nodes ▪ height & depth ▪ 4 traversal (DFS/BFS): in-order(left-root-right), pre-order(root-left-right), post-order(left-right-root), level-order ▪ proper, perfect, full, complete binary tree
Operations	▪ DFS: time O(n), space O(h) ▪ BFS: time O(n), space O(n)
Notes	stored in array or linked nodes
Hands-on	4 traversal

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LAB

Lab1

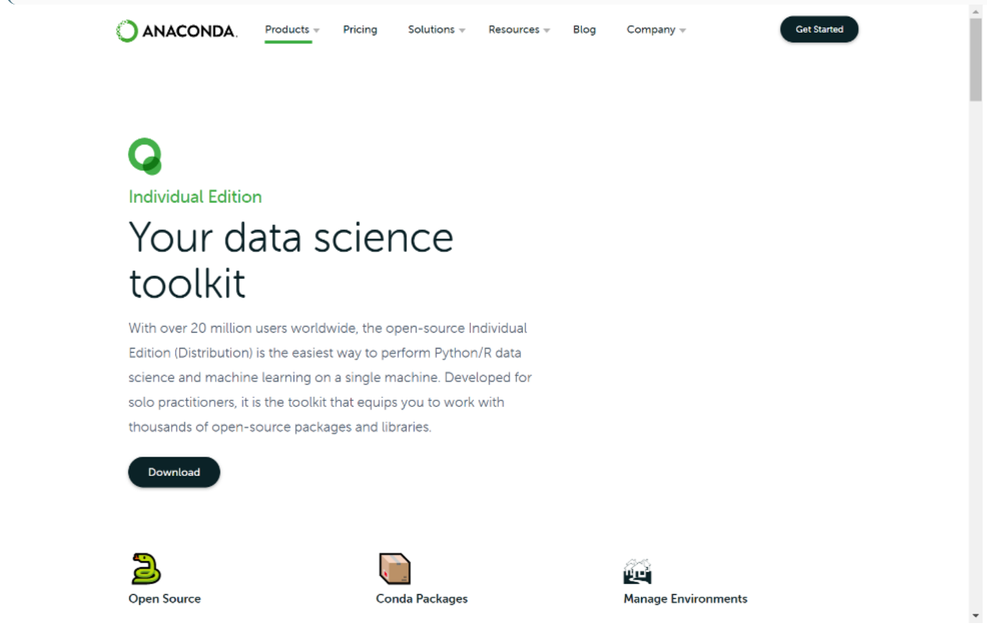
📋

- download and install Anaconda
- create and Activate your Anaconda Python env
- (Optional) install and setup VS Code
- familiar yourself with Python and do exercise 📝 lab1.ipynb

Lab1

Download and install Anaconda

https://www.anaconda.com/products/individual



Lab1

Create and Activate your Anaconda Python env

Lab1

Create and Activate your Anaconda Python env

💬 Also possible to perform via command line:

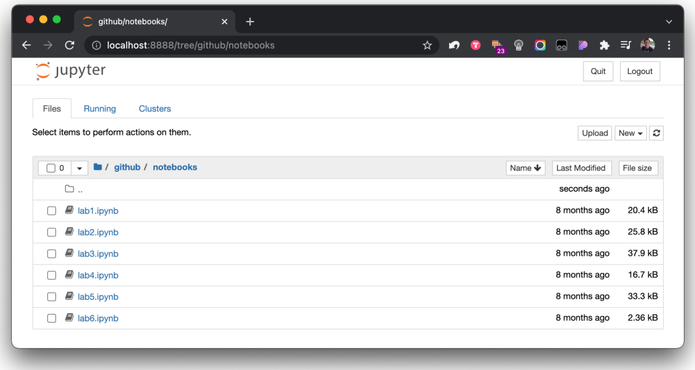
```
> # create the env
> conda create -n mth251 python=3.8
> # activate the env
> conda activate mth251
> # install jupyter
> conda install -c conda-forge notebook
> # multipledispatch for lab1
> conda install -c anaconda multipledispatch
> # start jupyter notebook
> jupyter notebook
```

- copy & paste the Jupyter link in the prompt to your browser
- Control-C to stop Jupyter from the command line

Lab1

Create and Activate your Anaconda Python env

6. Now you are ready to create, edit and run Jupyter notebooks (lab1.ipynb):



Lab1

VS Code

> VS Code now fully integrated with Jupyter notebook, refer to this link:
> Jupyter Notebooks in VS Code

Google Colab

> Google provides online Jupyter env:
> https://colab.research.google.com/

notebooks: https://github.com/fastzhong/mth251/tree/main/notebooks

Lab1

lab1.ipynb

- Python data type
- Python program structure
- OO

Lab2

📋

- review Array, Stack, Queue
- exercise 📝 lab2.ipynb
- priority queue
- circular queue

Lab2

Exercise 1: two sum

Given an array of integers nums and an integer target, return indices of the two numbers such that they add up to target.

You may assume that each input would have exactly one solution, and you may not use the same element twice.

Example 1

Input: *nums = [2,7,11,15], target = 9*

Output: *[0,1]*

Because nums[0] + nums[1] == 9, we return [0, 1]

Example 2

Input: *nums = [3,2,4], target = 6*

Output: *[1,2]*

Example 3

Input: *nums = [3,3], target = 6*

Output: *[0,1]*

Lab2

Exercise 2: remove duplicate numbers

Given a sorted array nums, remove the duplicates in-place such that each element appears only once and returns the new length.

Do not allocate extra space for another array, you must do this by modifying the input array in-place with O(1) extra memory.

Example 1

Input: *nums = [1,1,2]*

Output: *2, nums = [1,2]*

Explanation: Your function should return length = 2, with the first two elements of nums being 1 and 2 respectively. It doesn't matter what you leave beyond the returned length.

Example 2

Input: *nums = [0,0,1,1,1,2,2,3,3,4]*

Output: *5, nums = [0,1,2,3,4]*

Explanation: Your function should return length = 5, with the first five elements of nums being modified to 0, 1, 2, 3, and 4 respectively. It doesn't matter what values are set beyond the returned length.

Lab2

Priority Queue is similar to queue but the element with higher priority can be moved forward to the front. Use exiting Queue class to implement a priority queue (element with lower value has higher priority).

Priority Queue can be used in Printer Jobs or Schedule Tasks.

Lab2

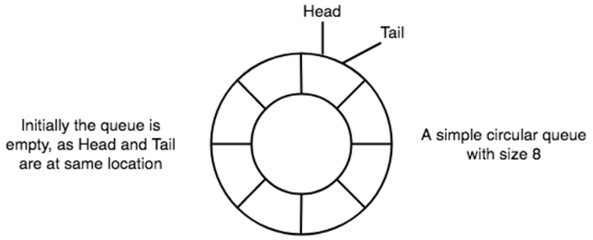
Circular Queue is a linear data structure in which the operations are performed based on FIFO (First In First Out) principle and the last position is connected back to the first position to make a circle. It is also called "Ring Buffer".

Design your implementation of circular queue.

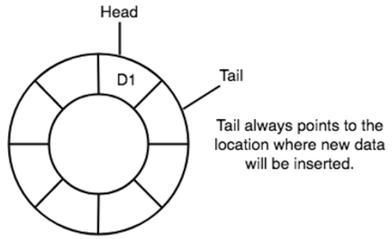
Lab2

Circular Queue

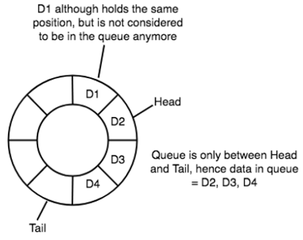
1. init



2. enqueue D1



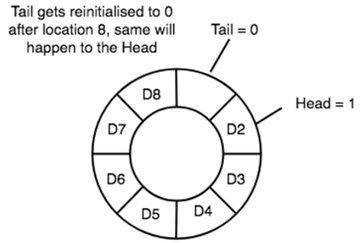
3. enqueue D2, D3, D4 and dequeue D1



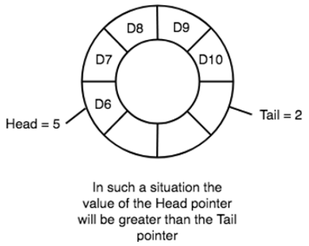
Lab2

Circular Queue

4. enqueue D5, D6, D7, D8



5. dequeue D2, D3, D4, D5 and enqueue D9, D10



Lab2

Circular Queue

One of the benefits of the circular queue is that we can make use of the spaces in front of the queue. In a normal queue, once the queue becomes full, we cannot insert the next element even if there is a space in front of the queue (and it does not prevent the program accidentally creates a large queue or stack and use up the memory).

Implementation of CircularQueue class:

- **enqueue**(): insert the element
- **dequeue**(): delete the element
- **front**(): return the first element in the queue, if queue is empty, return None
- **rear**(): return the last element in the queue, if queue is empty, return None
- **is_empty**(): return true if queue is empty
- **is_full**(): return true if queue is full

Lab3

📋

- linear search, binary search
- review Singly Linked List, Doubly Linked List, Recursion
- exercise 📝 lab3.ipynb

Lab3

binary search

1. Go to https://www.cs.usfca.edu/~galles/visualization/Search.html to understand how Linear Search & Binary Search is working

2. Implement Linear Search & Binary Search in Python by yourself:

- familiar with Python coding style
- understand the input, output, steps and ending condition
- learn and compare different approaches (time & space complexity)
- test code reliability with different cases

Lab3

- implement Stack by linked list
- implement Queue by linked list
- reverse a linked list
  - recursive implementation
  - iterative implementation

Lab4

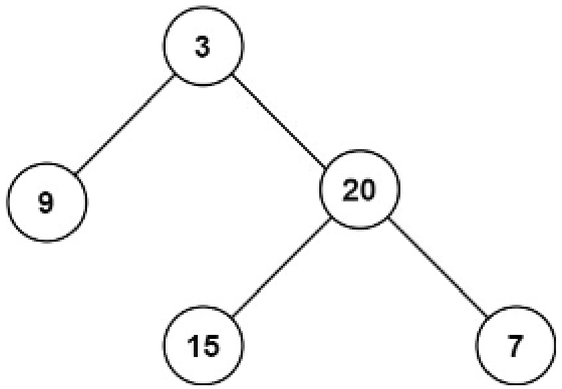
- review Binary Tree and 4 traverse methods
- exercise 📝 lab4.ipynb

Lab4

Exercise 1: get maximum depth of binary tree

A binary tree's maximum depth is the number of nodes along the longest path from the root node down to the farthest leaf node.

For example: the maximum depth is 3

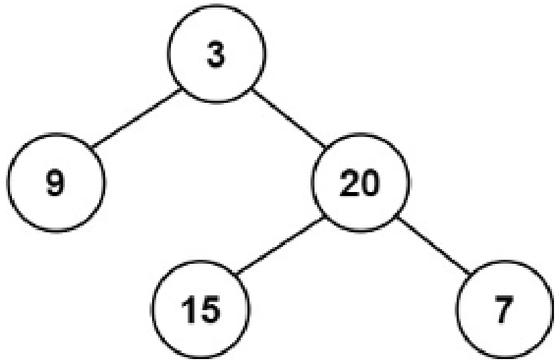


Lab4

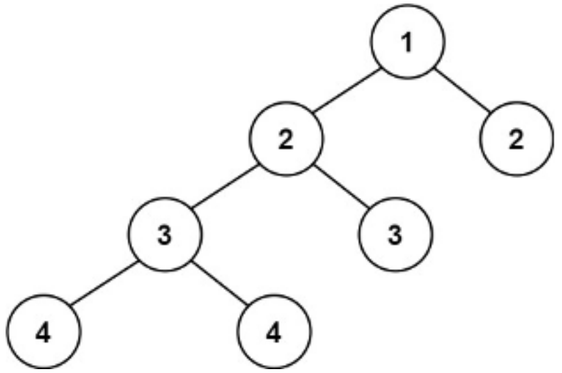
Exercise 2: check a balanced binary tree

A binary tree in which the left and right subtrees of every node differ in height by no more than 1.

balanced = true:



balanced = false:

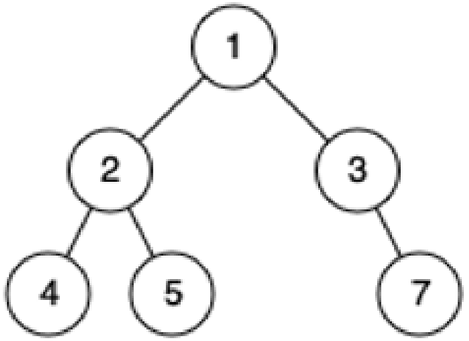


Lab4

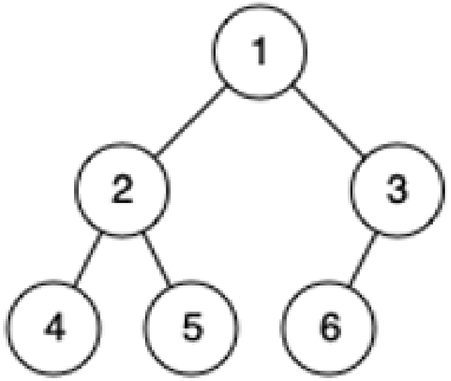
Exercise 3: check a complete binary tree

In a complete binary tree, every level, except possibly the last, is completely filled, and all nodes in the last level are as far left as possible. It can have between 1 and 2h nodes inclusive at the last level h.

complete = true:



complete = false:



Lab5

📋

- exercise 📝 lab5.ipynb

Lab6

📋

- exercise 📝 lab6.ipynb