Chapter 3: Stacks

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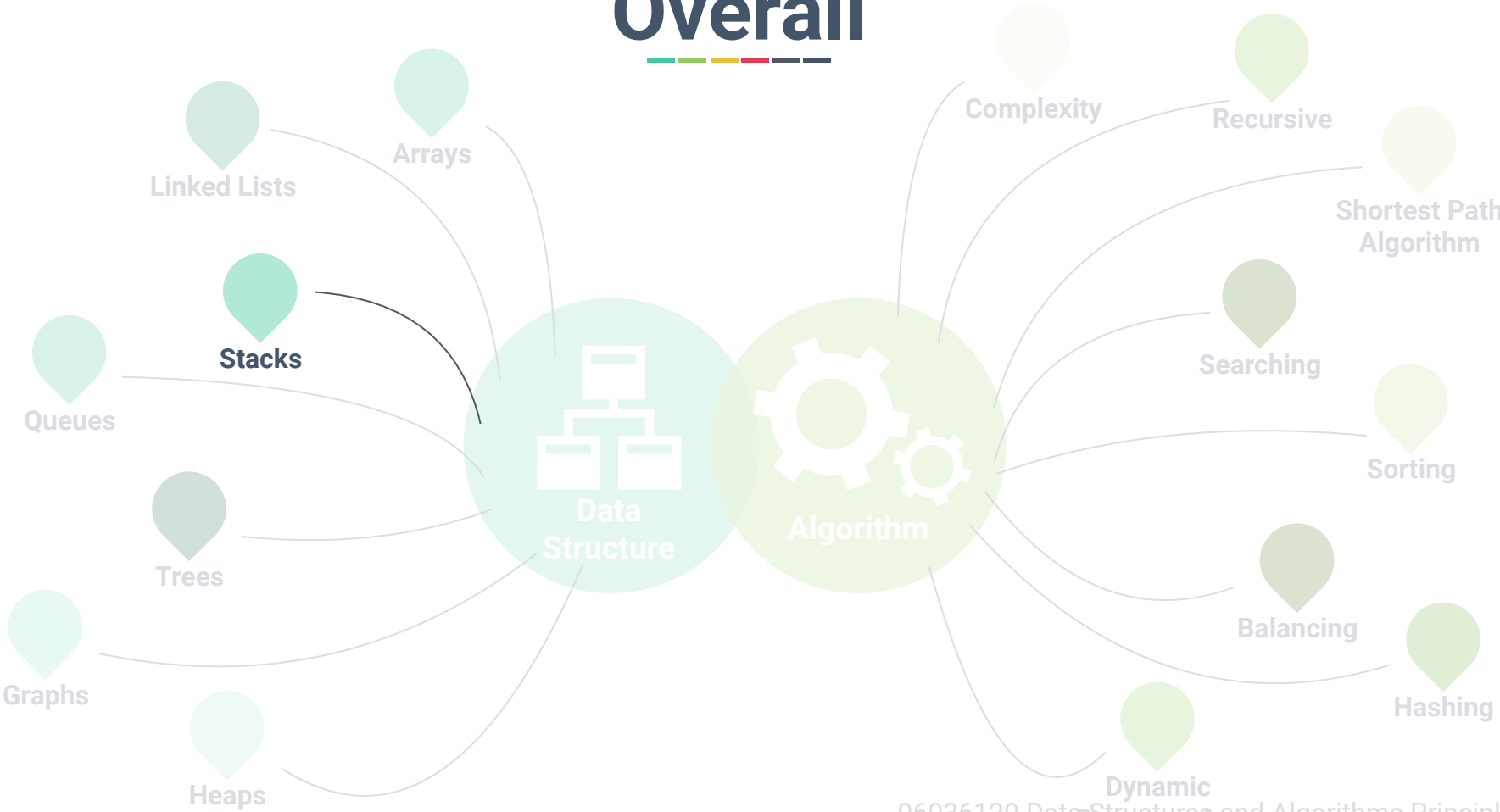
Overall


Linked Lists
Arrays
Stacks
Queues
Trees
Graphs
Heaps
Data Structure
Algorithm
Complexity
Recursive
Shortest Path Algorithm
Searching
Sorting
Balancing
Hashing
Dynamic Programming

Today's Outline

1. What is a Stack?
2. Stack Abstract Data Type
3. Simple Array-Based Stack Implementation
4. Stack Applications

Linear Data Structures

- Items are ordered depending on how they are added or removed.
  - Arrays
  - Stacks
  - Queues

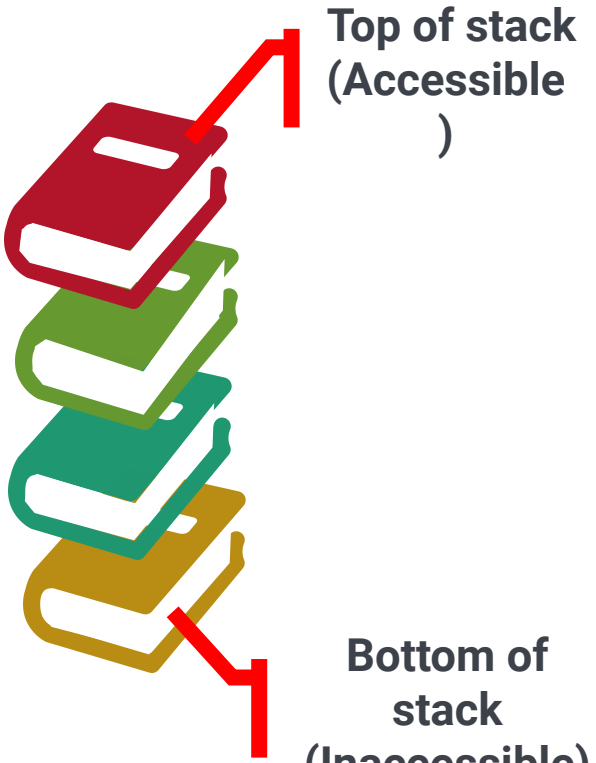
What is a Stack?

A stack is a collection of objects that are inserted and removed according to the ***last-in first-out*** **(*LIFO*)** principle [1].

The name “stack” is derived from the metaphor of a stack of plates in a plate dispenser.

[1] Michael T. Goodrich et al., Data Structures and Algorithms in Python, 2013

Stack of Books



Stack Abstract Data Type

To create an instance of a stack, use Stack().

Formally, there are 2 main operations of stacks:

1) push(item)

2) pop()

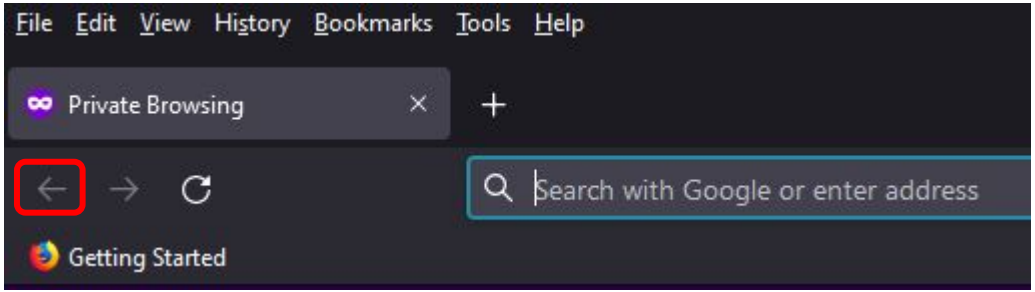
[1] Michael T. Goodrich et al., Data Structures and Algorithms in Python, 2013

Stack of Books

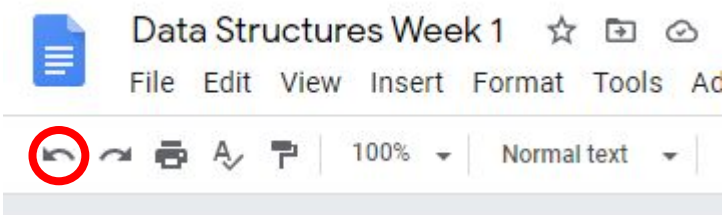
Push
a new book on the top

Pop
a book from the top

Stack Applications Example



Web Browser's history of recently visited sites.



The undo button.

Stack's Operations

Additional operations of stacks:

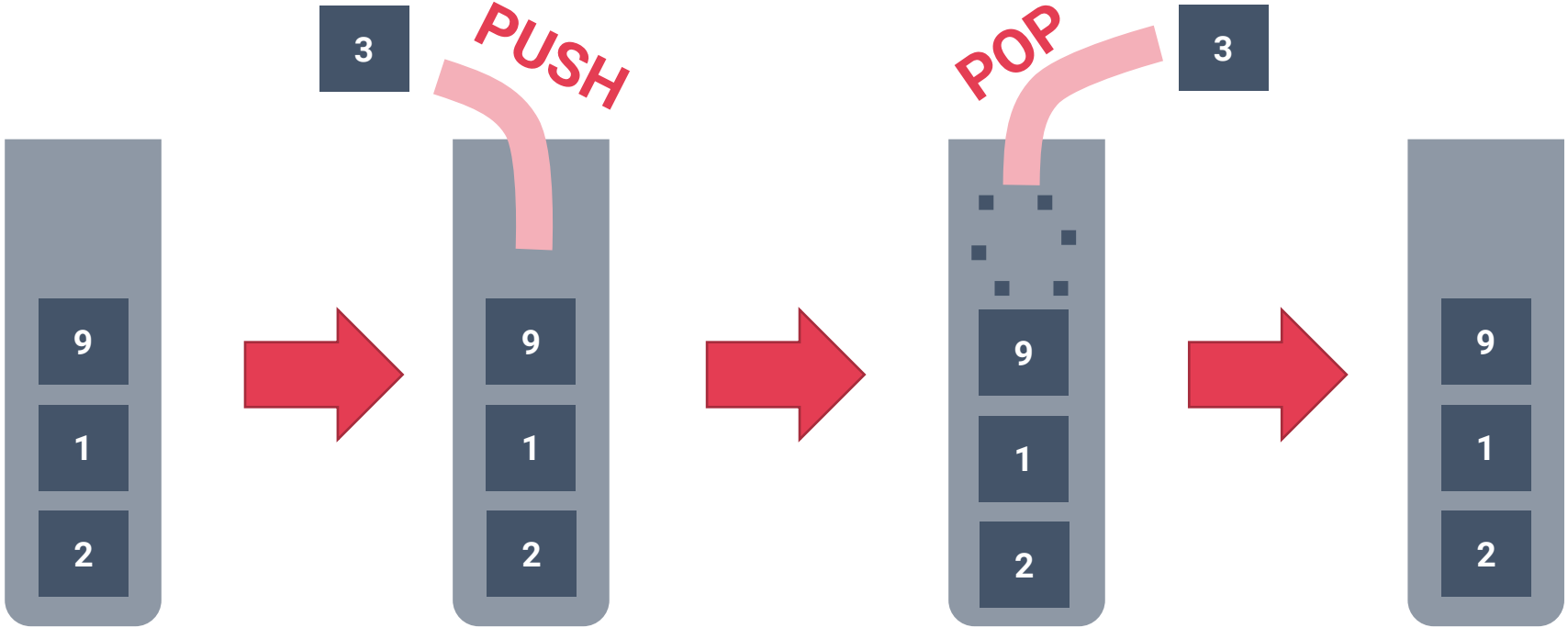
1) top()
2) is_empty()
3) len(Stack)

[1] Michael T. Goodrich et al., Data Structures and Algorithms in Python, 2013

Stack Implementation

How to Implement a Stack?

Stack Implementation



Stack's Operation Example

Operation	Return Value
S.push(9)	
S.push(5)	
S.top()	
S.push(2)	
S.pop()	
S.is_empty()	
len(S)	

Stack

Asymptotic Performance

Operation	Running Time
S.push(element)	$O(1)$
S.pop()	$O(1)$
S.top()	$O(1)$
S.is_empty()	$O(1)$
len(S)	$O(1)$

Stack Implementation

How to Implement a Stack using a Python?

Stack Implementation

Create ArrayStack class and its methods

[2]
```
class ArrayStack:
  def __init__(self):
    """ Create an empty stack. """
    self._data = []   # Initiate a nonpublic list instance

  def __len__(self):
    """ Return the number of elements in the stack. """
    return len(self._data)

  def is_empty(self):
    """ Return True if the stack is empty. """
    return len(self._data) == 0

  def push(self, element):
    """ Add an element to the top of the stack. """
    self._data.append(element) # new item stored at end of list

```

Stack Implementation

```
18  def top(self):
19    """ Return (but do not remove) the element at the top of the stack.
20    Raise an exception if the stack is empty. """
21    if self.is_empty():
22      print('Stack is empty')
23      raise Empty('Stack is empty') # Calling subclass Empty
24    return self._data[-1] # the last item in the list
25
26  def pop(self):
27    """ Remove and return the element from the top of the stack.
28    Raise an exception if the stack is empty. """
29    if self.is_empty():
30      print('Stack is empty')
31      raise Exception('Stack is empty') # Alternate way to call subclass Empty
32    return self._data.pop() # remove last item from the list
33
```

```
[3]  1 class Empty(Exception):
     2   """ Error attempting to access an element from an empty container. """
     3   pass
```

Stack Applications

1) Simple Balanced Parentheses

Each opening symbol must match its corresponding closing symbol.

Parentheses:

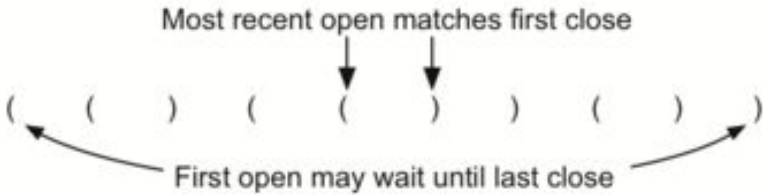
Examples

Balanced:

Unbalanced:

Simple Balanced Parentheses

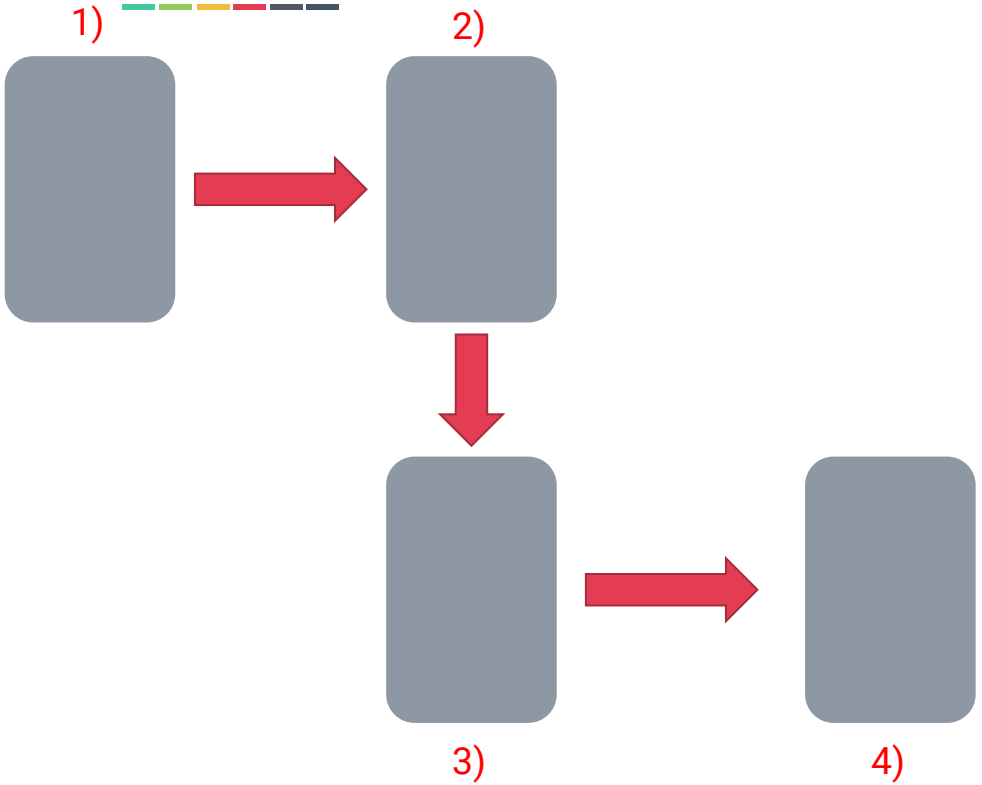
How to check balanced parentheses?



Ref: https://runestone.academy/runestone/books/published/pythonds/BasicDS/SimpleBalancedParentheses.html

Simple Balanced Parentheses

Example: (1 + x - (y + z))



Balanced Parentheses Algorithm

IsBalanced(str):

Stack Applications

2) Balanced Grouping Symbols

Each opening symbol must match its corresponding closing symbol.

Parentheses:
Brackets:
Braces:

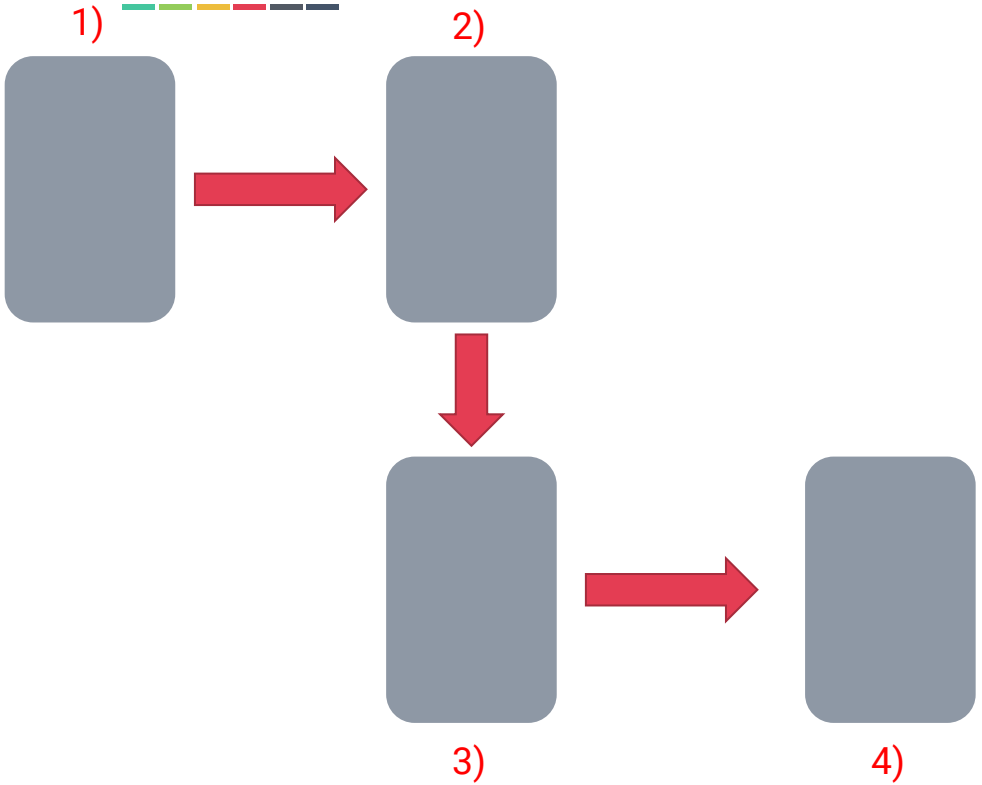
Examples

Balanced:

Unbalanced:

Balanced Grouping Symbols

Example: (1 + x - [y + z])



Balanced Symbols Algorithm

IsBalanced(str):

```
s = ArrayStack()
    ...
    ...
    ...
    ...
    ...
return s.is_empty()
```