



香港中文大學(深圳)

The Chinese University of Hong Kong, Shenzhen

Introduction to Computer Science: Programming Methodology

Lecture 9 Recursion, Stack and Queue

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Linear Recursion

- If a recursive function is designed so that each invocation of the body makes **at most one** new recursive call, this is known as **linear recursion**
- Finding the factorial and binary search are both linear recursive algorithms

Practice: Sum of a list

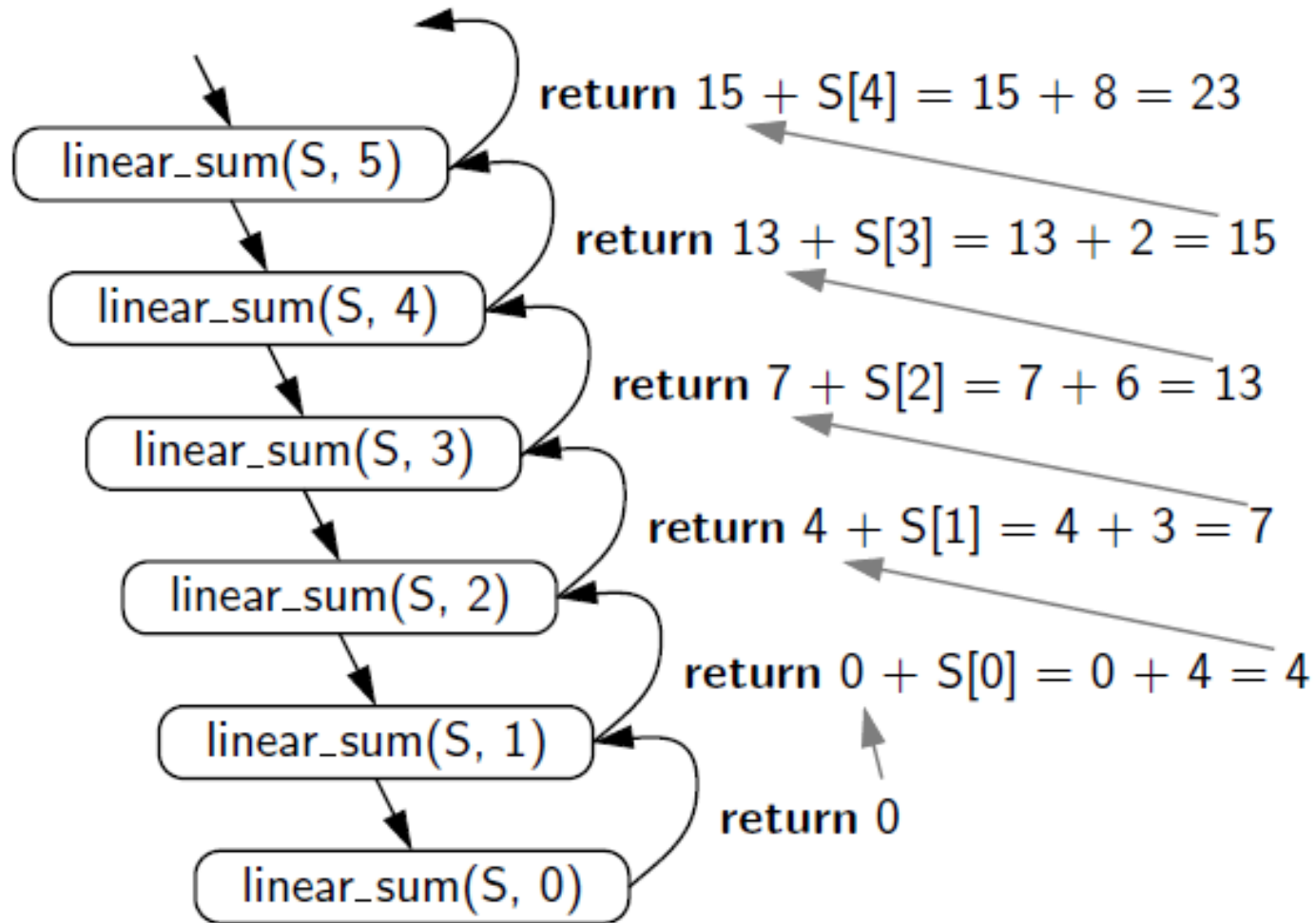
- Given a list of numbers, write a program to calculate the sum of this list using recursion

Solution:

$$\text{sum}(L, n) = \begin{cases} 0 & \text{if } n=0 \\ \text{sum}(L, n-1) + L[n-1] & \text{if } n>0 \end{cases}$$

```
def linearSum(L, n):  
    if n==0:  
        return 0  
    else:  
        return linearSum(L, n-1)+L[n-1]  
  
def main():  
    L = [1, 2, 3, 4, 5, 9, 100, 46, 7]  
    print('The sum is:', linearSum(L, len(L)))
```

The recursive trace for recursive sum



Practice: Power function

- Write a program to calculate the power function $f(x, n) = x^n$ using Recursion. The time complexity of the program should be $O(\log n)$

A better recursive definition of power function

$$power(x, n) = \begin{cases} 1 & \text{if } n = 0 \\ x \cdot (power(x, \lfloor \frac{n}{2} \rfloor))^2 & \text{if } n > 0 \text{ is odd} \\ (power(x, \lfloor \frac{n}{2} \rfloor))^2 & \text{if } n > 0 \text{ is even} \end{cases}$$

Solution:

```
def myPower(x, n) :  
    if n==0:  
        return 1  
    else:  
        partial = myPower(x, n//2)  
        result = partial * partial  
        if n%2==1:  
            result = result * x  
    return result
```

SB 3
SB 3

Multiple recursion

- When a function makes **two or more** recursive calls, we say that it uses **multiple recursion**
- Drawing the English ruler is a multiple recursion program

Practice: Binary sum

- Write a function `binarySum()` to calculate the sum of a list of numbers. Inside `binarySum()` two recursive calls should be made

Solution:

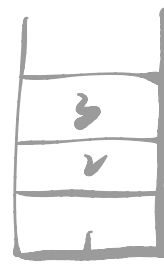
```
def binarySum(L, start, stop):  
    if start >= stop:  
        return 0  
    elif start == stop - 1:  
        return L[start]  
    else:  
        mid = (start + stop) // 2  
        return binarySum(L, start, mid) + binarySum(L, mid, stop)
```

求和总要一个个加起来
→ $O(n)$

```
def main():  
    L = [1, 2, 3, 4, 5, 6, 7]  
    print(binarySum(L, 0, len(L)))
```

Stack

堆棧



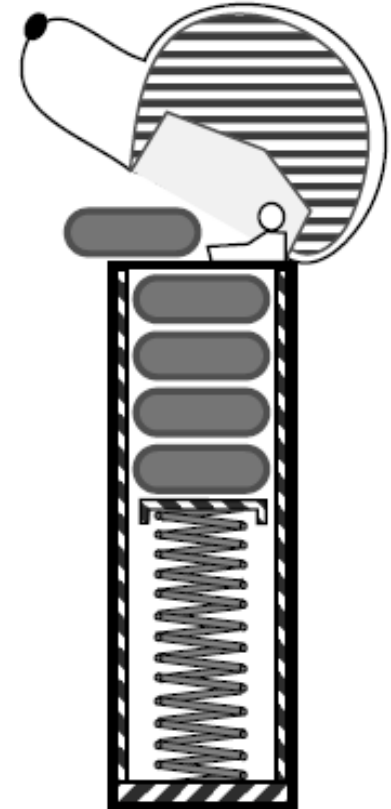
in: 1 → 2 → 3
out: 3 → 2 → 1
(remove)

(data)

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

First-in, Last out (FILO)

- A user may **insert** objects into a stack **at any time**, but may only access or remove the most recently inserted object that remains (**at the so-called "top" of the stack**)



Example: Web Browser

- Internet Web browsers store the addresses of recently visited sites in a stack. Each time a user visits a new site, that site's address is “pushed” onto the stack of addresses. The browser then allows the user to “pop” back to previously visited sites using the “back” button.

Example: Text editor

- Text editors usually provide an “undo” mechanism that cancels recent editing operations and reverts to former states of a document. This undo operation can be accomplished by keeping text changes in a stack.

Data Structure: How to save & use data
access

Stack 第4个数据结构

The stack class

(堆栈)

- Generally, a stack may contain the following methods:

S.push(e): Add element e to the top of stack S.

S.pop(): Remove and return the top element from the stack S;
an error occurs if the stack is empty.

移除后要返回

S.top(): Return a reference to the top element of stack S, without removing it; an error occurs if the stack is empty.

只返回不删除

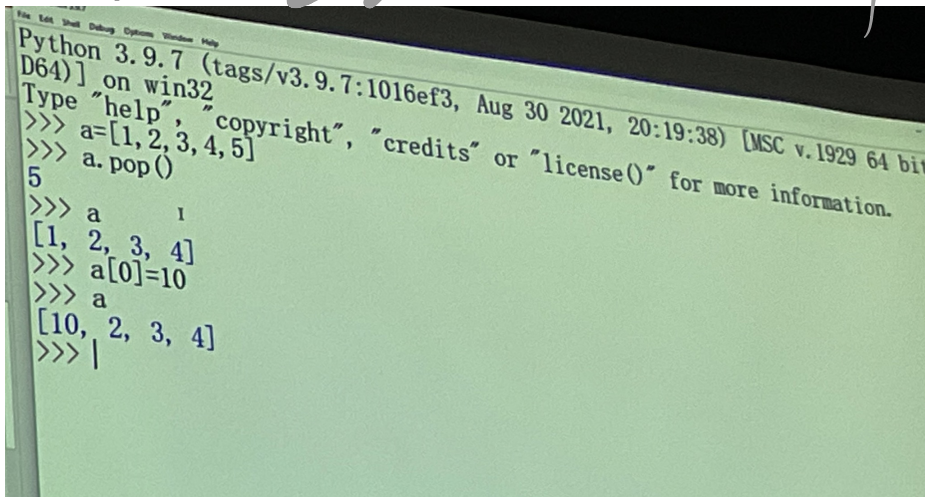
S.is_empty(): Return True if stack S does not contain any elements.

len(S): Return the number of elements in stack S; in Python, we implement this with the special method `__len__`.

The Code of Stack Class

可访问任何元素

list ↔ stack: 不一样!



```
Python 3.9.7 (tags/v3.9.7:1016ef3, Aug 30 2021, 20:19:38) [MSC v.1929 64 bit  
D64] on win32  
Type "help()", "copyright()", "credits()", or "license()" for more information.  
>>> a=[1,2,3,4,5]  
>>> a.pop()  
5  
>>> a  
[1, 2, 3, 4]  
>>> a[0]=10  
>>> a  
[10, 2, 3, 4]  
>>> |
```

class ListStack:

私有的一切让别人没法访问
不想让他访问的东西

```
def __init__(self):  
    self.__data = list()  
  
def __len__(self):  
    return len(self.__data)  
  
def is_empty(self):  
    return len(self.__data) == 0  
  
def push(self, e):  
    self.__data.append(e)  
  
def top(self):  
    if self.is_empty():  
        print('The stack is empty.')  
    else:  
        return self.__data[self.__len__()-1]  
  
def pop(self):  
    if self.is_empty():  
        print('The stack is empty.')  
    else:  
        return self.__data.pop()
```


The code to use stack class



```
def main():  
    s = ListStack()  
    print('The stack is empty? ', s.is_empty())  
    s.push(100)  
    s.push(200)  
    s.push(300)  
    300 ← print(s.top())  
    300 ← print(s.pop())  
    200 ← print(s.top())
```

Practice: Reverse a list using stack

- Write a program to reverse the order of a list of numbers using the stack class

Solution:

```
from stack import ListStack

def reverse_data(oldList):
    s = ListStack()
    newList = list()

    for i in oldList:
        s.push(i)

    while (not s.is_empty()):
        mid = s.pop()
        newList.append(mid)

    return newList

def main():
    oldList = [1, 2, 3, 4, 5]
    newList = reverse_data(oldList)
    print(newList)
```

Practice: Brackets match checking

- In correct arithmetic expressions, the opening brackets must match the corresponding closing brackets. Write a program to check whether all the opening brackets have matched closing brackets.

Solution:

```
from stack import ListStack

def is_matched(expr):
    lefty = '([{'
    righty = ')]}'

    s = ListStack()

    for c in expr:
        if c in lefty:
            s.push(c)
        elif c in righty:
            if s.is_empty():
                return False
            if righty.index(c) != lefty.index(s.pop()):
                return False
    return s.is_empty()

def main():
    expr = '1+2*(3+4)-[5-6]'
    print(is_matched(expr))
    expr = '((( )))]'
    print(is_matched(expr))
```

Practice: Matching Tags in HTML Language

- HTML is the standard format for hyperlinked documents on the Internet
- In an HTML document, portions of text are delimited by HTML tags. A simple opening HTML tag has the form “<name>” and the corresponding closing tag has the form “</name>”

HTML Tags

- Commonly used HTML tags that are used in this example include
 - body: document body
 - h1: section header
 - center: center justify
 - p: paragraph
 - ol: numbered (ordered) list
 - li: list item

An example of HTML document

有特定的功能
tag
标签
come in pairs

```
<body>
<center>
<h1> The Little Boat </h1>
</center>
<p> The storm tossed the little
boat like a cheap sneaker in an
old washing machine. The three
drunken fishermen were used to
such treatment, of course, but
not the tree salesman, who even as
a stowaway now felt that he
had overpaid for the voyage. </p>
<ol>
<li> Will the salesman die? </li>
<li> What color is the boat? </li>
<li> And what about Naomi? </li>
</ol>
</body>
```

(a)

终止的 tag

The Little Boat

The storm tossed the little boat like a cheap sneaker in an old washing machine. The three drunken fishermen were used to such treatment, of course, but not the tree salesman, who even as a stowaway now felt that he had overpaid for the voyage.

1. Will the salesman die?
2. What color is the boat?
3. And what about Naomi?

(b)

Solution:

```
from stack import ListStack

def is_matched_html(raw):
    s = ListStack()
    j = raw.find('<')
    while j != -1:
        k = raw.find('>', j+1)
        if k == -1:
            return False
        tag = raw[j+1:k]

        if not tag.startswith('/'):
            s.push(tag)
        else:
            if s.is_empty():
                return False
            if tag[1:] != s.pop():
                return False
            j = raw.find('<', k+1)

    return s.is_empty()

def main():
    fhand = open('sampleHTML.txt', 'r')
    raw = fhand.read()
    print(raw)
    print(is_matched_html(raw))
```

Solution:

```
from stack import ListStack

def is_matched_html(raw):
    s = ListStack()
    j = raw.find('<')

    while j != -1:
        k = raw.find('>', j+1)
        if k == -1:
            return False
        tag = raw[j+1:k]

        if not tag.startswith('/'):
            s.push(tag)
        else:
            if s.is_empty():
                return False
            if tag[1:] != s.pop():
                return False
            j = raw.find('<', k+1)

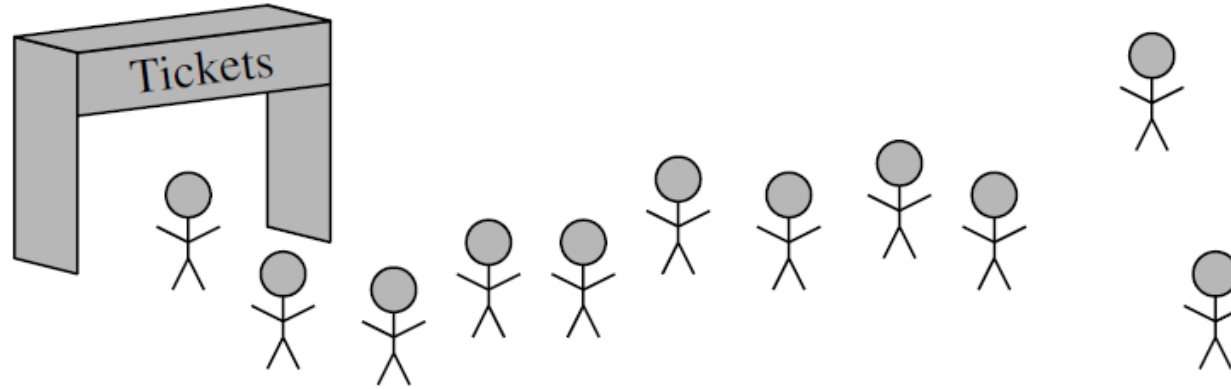
    return s.is_empty()

def main():
    fhand = open('sampleHTML.txt', 'r')
    raw = fhand.read()
    print(raw)
    print(is_matched_html(raw))
```

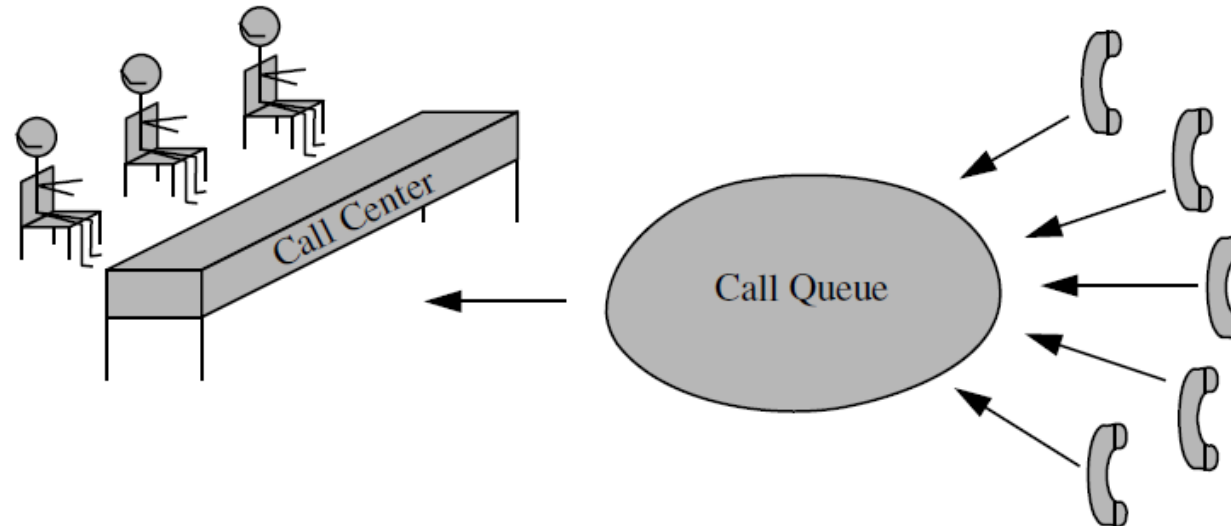
Queue 队列

- **Queue** is another fundamental data structure
- A queue is a collection of objects that are inserted and removed according to the **first-in, first-out (FIFO)** principle
- Elements can be inserted **at any time**, but only the element that has been in the queue **the longest** can be next removed

Applications of Queue



(a)



(b)

The queue class

- The queue class may contain the following methods:

`Q.enqueue(e)`: Add element `e` to the back of queue `Q`.

`Q.dequeue()`: Remove and return the first element from queue `Q`;
an error occurs if the queue is empty.

`Q.first()`: Return a reference to the element at the front of queue `Q`,
without removing it; an error occurs if the queue is empty.

`Q.is_empty()`: Return `True` if queue `Q` does not contain any elements.

`len(Q)`: Return the number of elements in queue `Q`; in Python,
we implement this with the special method `__len__`.

The code of queue class

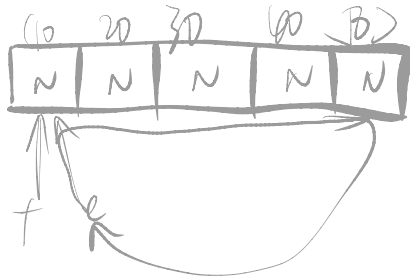
static datafield 静态数据域
`class ListQueue:`
 `default_capacity = 5`

`def __init__(self):`
 `self.__data = [None]*ListQueue.default_capacity`
 `self.__size = 0`
 `self.__front = 0`
 `self.__end = 0`

`def __len__(self):`
 `return self.__size`

`def is_empty(self):`
 `return self.__size == 0`

`def first(self):`
 `if self.is_empty():`
 `print('Queue is empty.')`
 `else:`
 `return self.__data[self.__front]`



`def dequeue(self):`

`if self.is_empty():`
 `print('Queue is empty.')`
 `return None`

`answer = self.__data[self.__front]`
 `self.__data[self.__front] = None`
 `self.__front = (self.__front+1) \`
 `% ListQueue.default_capacity`
 `self.__size -= 1`
 `return answer`

`def enqueue(self, e):`
 `if self.__size == ListQueue.default_capacity:`
 `print('The queue is full.')`
 `return None`

 `self.__data[self.__end] = e`
 `self.__end = (self.__end+1) \`
 `% ListQueue.default_capacity`
 `self.__size += 1`

*eg = ListQueue()
lq.enqueue(10)
lq.enqueue(20)
lq.enqueue(30)
lq.enqueue(40)
lq.enqueue(50)*

`def outputQ(self):`
 `print(self.__data)`

*方法2: data = []
 append(10)
 :*

内存空间会要大

The code of queue class

```
class ListQueue:
    default_capacity = 5

    def __init__(self):
        self.__data = [None]*ListQueue.default_capacity
        self.__size = 0
        self.__front = 0
        self.__end = 0

    def __len__(self):
        return self.__size

    def is_empty(self):
        return self.__size == 0

    def first(self):
        if self.is_empty():
            print('Queue is empty.')
        else:
            return self.__data[self.__front]

    def dequeue(self):
        if self.is_empty():
            print('Queue is empty.')
            return None

        answer = self.__data[self.__front]
        self.__data[self.__front] = None
        self.__front = (self.__front+1) \
            % ListQueue.default_capacity
        self.__size -= 1
        return answer

    def enqueue(self, e):
        if self.__size == ListQueue.default_capacity:
            print('The queue is full.')
            return None

        self.__data[self.__end] = e
        self.__end = (self.__end+1) \
            % ListQueue.default_capacity
        self.__size += 1

    def outputQ(self):
        print(self.__data)
```

Practice: Simulating a web service

- An online video website handles service requests in the following way:
 - 1) It maintains a service queue which stores all the unprocessed service requests.
 - 2) When a new service request arrives, it will be saved at the end of the service queue. 服务队列
 - 3) The server of the website will process each service request on a “first-come-first-serve” basis. 服务器
- Write a program to simulate this process. The processing time of each service request should be randomly generated.

Solution

```
from ListQueue import ListQueue
from random import random
from math import floor

class WebService():
    default_capacity = 5
    def __init__(self):
        self.nameQ = ListQueue()
        self.timeQ = ListQueue()

    def taskArrive(self, taskName, taskTime):
        if self.nameQ.__len__() < WebService.default_capacity:
            self.nameQ.enqueue(taskName)
            self.timeQ.enqueue(taskTime)
            print('A new task 《'+taskName+'》 has arrived and is waiting for processing...')
        else:
            print('The service queue of our website is full, the new task is dropped.')

    def taskProcess(self):
        if (self.nameQ.is_empty() == False):
            taskName = self.nameQ.dequeue()
            taskTime = self.timeQ.dequeue()
            print('Task 《'+taskName+'》 has been processed, it costs '+str(taskTime)+' seconds.')
```

Solution

```
def main():
    ws = Webservice()
    taskNameList = ['Dark knight', 'X-man', 'Kungfu', 'Shaolin Soccer', 'Matrix', 'Walking in the clouds' \
                    , 'Casino Royale', 'Bourne Supremacy', 'Inception', 'The Shawshank Redemption']

    print('Simulation starts...')
    print('-----')
    for i in range(1, 31):
        rNum = random()
        if rNum<=0.6:
            taskIndex = floor(random()*10)
            taskTime = floor(random()*1000)/100
            ws.taskArrive(taskNameList[taskIndex], taskTime)
        else:
            ws.taskProcess()
    print('-----')
    print('Simulation finished.')
```