

Linear List

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1. Array

1.1 Overview of Array

在本节中，我们首先来思考一下数组是什么？

3	1	4	5	6	7
---	---	---	---	---	---

这是一个数组:[3,1,4,5,6,7], 它本质上就是在一段连续的内存片段上存储的一串数据, 由于 int 占了四个字节, 所以每一个数组元素的地址相差四位。

接下来分析数组中常见的操作的算法复杂度:

- Lookup $O(1)$ 根据索引去查找元素, 由于数组中可以通过中括号访问符进行访问, 所以不论访问哪一个元素, 算法复杂度均为 $O(1)$
- Insert $O(n)$ 进行元素插入, 如果在末尾进行元素插入, 算法复杂度为 $O(1)$, 但是如果在第一位插入, 我们就需要将每一位都往后挪动一位, 所以复杂度为 $O(n)$, 通常我们都考虑最坏的情况, 所以算法复杂度为 $O(n)$
- Delete $O(n)$ 无论删除哪一个元素, 其他元素都需要往前移动一位, 所以最终算法复杂度为 $O(n)$

1.2 Practice: To create an Array Class with Java

■ **Example 1.1** 在 Java 中, 创建一个 MikeArray 类型, 要求要满足以下几点, 1. 具有 insert 方法, 可以在数组末尾插入元素, 2. 具有 removeAt(int index) 方法, 在 index 处删除对应的元素, 3. 实现 print 方法, 打印出数组中所有的元素 4. indexOf 方法, 返回目标元素第一次出现在数组中的索引, 如果没有出现元素, 则返回索引-1, 4. 动态扩充, 在使用 insert 方法的时候如果超出了数组本身的长度, 扩容到原数组容量的 2 倍, 5. 构造方法是给出数组的长度 length 进行数组构造的。 ■

```
public class MArray {  
    private int[] items;  
    private int count=0;  
    public MArray(int length){  
        items=new int[length];  
    }  
  
    public void print(){  
        for(int i=0;i<count;i++){  
            System.out.println(items[i]);  
        }  
    }  
  
    public void insert(int element){  
        //if the array is full  
        if(items.length==count){  
            //Create a new array (twice the size)  
            int array[]=new int[count*2];  
            //Copy all the items into new Array  
            for(int i=0;i<count;i++){  
                array[i]=items[i];  
            }  
            //set the items to the new array  
            items=array;  
        }  
        items[count++]=element;  
    }  
  
}
```

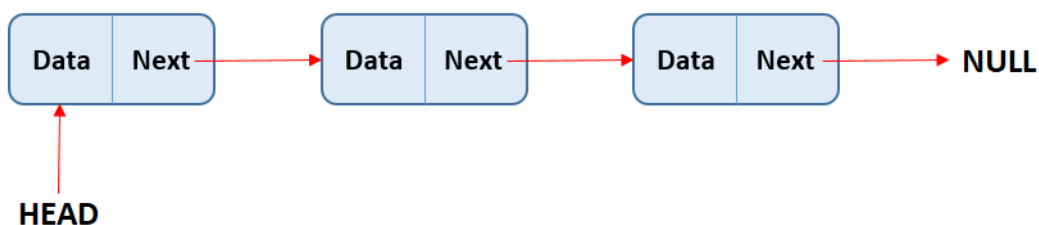
```
        public void removeAt(int index){
            if(index<0||index>=count){
                throw new IllegalArgumentException();
            }
            else{
                //[10,20,30,40]
                // index:1
                for(int i=index;i<count;i++){
                    items[i]=items[i+1];
                }
                count--;
            }
        }

        public int indexOf(int item){
            //获取元素的位置
            //肯定是有可能遍历完整个都没有存在的
            for(int i=0;i<count;i++){
                if(items[i]==item){
                    return i;
                }
            }
            return -1;
        }
    }
```


2. LinkedList

2.1 Overview of LinkedList

链表是由一串节点 (Node) 连接而成, 这个节点由两部分组成, 一部分是数据 Data, 另外一部分是指针 Pointer, 每一个 Node 的指针都指向了下一个节点。一般的链表具有头节点, 当然也有的具有尾节点, 除了一般的单向链表, 还有一种双向链表, 在双向链表中每一个节点都具有两个指针, 一个指向之前的节点, 一个指向了之后的节点。但是总体上来说, 链表的结构都大同小异。



2.2 LinkedList In Java

在 Java 中就有 LinkedList, 常用的方法有:

- addFirst 在链表首添加元素
- addLast 在链表尾部添加元素
- contains 是否包含元素
- isEmpty 判断链表是否为空
- indexOf 返回链表中某一元素的位置

这些方法都是由 Java 内部进行实现的, 我们直接引入 LinkedList 这个类即可直接使用, 当然在下一节中, 我们将开始写属于我们自己的链表 (MikeLinkedList)。


```
LinkedList<Integer>linkedList=new LinkedList<>();
linkedList.addFirst(10);
linkedList.addFirst(10);
linkedList.addFirst(10);
System.out.println(linkedList.indexOf(10));
System.out.println(linkedList.contains(10));
System.out.println(linkedList.isEmpty());
linkedList.addLast(29);
System.out.println(linkedList);
```

2.3 MikeLinkedList 的搭建 1: 完成 Node Class 的实现与 MikeLinkedList 的基础

在第一节中我们说明了链表是由一个一个节点组成的，所以首先实现一个 Node Class(Integer 整型)，使用整数进行示范，不设置为泛型。

```
public class Node {
    public Node(int value){
        this.value=value;
    }

    public int value;//当前节点的值
    public Node next;//指向下一个节点的指针
}
```

然后完成 MikeLinkedList 的搭建，这个链表首先要两个节点，一个是首节点，一个是尾节点，还需要设置一个 size 属性，记录链表的长度。

```
public class MikeLinkedList{
    //头节点 p
    private Node First;
    private Node Last;
    private int Size;
}
```

2.4 MikeLinkedList 的搭建 2: 实现具体的方法

在实现过程中，要考虑极限情况，没有元素的时候，只有一个元素的时候。

2.4.1 addFirst

实现方法很简单，新建一个节点，将它标记为头节点，然后把它的 next 指针指向原本的头节点即可，算法复杂度 $O_n = 1$

```
public void addFirst(int value) {  
    var node = new Node(value);  
    //当前链表是否为空  
    if (isEmpty()) {  
        First = Last = node;  
    } else {  
        var temp = First;  
        First = node;  
        First.next = temp;  
        size++;  
    }  
}
```

2.4.2 addLast

addLast 方法也非常简单，只需要设置将最后一个节点的 next 指向新节点，然后将 Last 标记为最后一个节点即可，算法复杂度为 $O_n = 1$

```
public void addLast(int value) {  
    var node = new Node(value);  
    if (isEmpty()) {  
        First = Last = node;  
    } else {  
        Last.next = node;  
        Last = node;  
    }  
    size++;  
}
```

2.4.3 isEmpty

isEmpty 只需要判断头节点是否为空，如果为空的话就说明这个链表为空，非常简单

```
private boolean isEmpty() {  
    return First == null;  
}
```

2.4.4 indexOf

实现 indexOf 方法只需要从链表头开始遍历，直到发现某个节点的 value 和目标节点的 value 是一样的，如果一样就返回对应的 index，如果遍历完整个链表都没有发现目标，则返回-1。由于在最坏的情况需要完整遍历一遍链表，所以算法复杂度为 $O_n = n$ 。

```
public int indexOf(int value) {  
    if (isEmpty()) {  
        return -1;  
    } else {  
        var cur = First;  
        var index = 0;  
        while (cur != null) {  
            if (cur.value == value) {  
                return index;  
            }  
            index++;  
            cur = cur.next;  
        }  
    }  
    return -1;  
}
```

2.4.5 contains

contains 方法的实现在 indexOf 写过之后就变得非常简单，只需要执行一次 indexOf 方法，如果返回的是-1，则表示不包含，返回 false，否则返回 true

```
public boolean contains(int value) {  
    return indexOf(value) != -1;  
}
```

2.4.6 removeFirst

removeFirst 方法的核心是将第二个节点设置为 First，然后将第一个节点解除关联。

```
public void removeFirst() {  
    if (isEmpty()) {  
        throw new NoSuchElementException();  
    }  
    if (First.next == null) {  
        First = Last = null;  
        return;  
    } else {  
        var second = First.next;  
        First.next = null;  
        First = second;  
    }  
    size--;  
}
```

2.4.7 removeLast

要实现 removeLast 稍微比 removeFirst 难一些，因为我们的思路应该还是找到 Last 之前的那个节点，然后把最后一个节点引用解除，设置倒数第二个节点为 Last 即可。但是如何获取倒数第二个节点？我们可以先写一个 getPrevious 的函数，然后再写这个函数

```
public Node getPrevious(Node node) {  
    var current = First;  
    while (current != null) {  
        if (current.next == node) {  
            return current;  
        }  
        current = current.next;  
    }  
    return null;  
}
```

```
public void removeLast() {  
    if (isEmpty()) {  
        throw new NoSuchElementException();  
    } else if (First == Last) {  
        First = Last = null;  
    } else {  
        var previous = getPrevious(Last);  
        Last = previous;  
        Last.next = null;  
    }  
    size--;  
}
```

2.4.8 toArray

将链表转为数组，方法很简单，遍历一遍，把链表的元素装数组里即可

```
public int[] toArray() {  
    int[] array = new int[size];  
    var cur = First;  
    var index = 0;  
    while (cur != null) {  
        array[index] = cur.value;  
        cur = cur.next;  
        index++;  
    }  
    return array;  
}
```

2.5 练习题 1: 反转链表

■ **Example 2.1** 将链表反转，比如 10→20→30→40→50 反转为 50→40→30→20→10。仔细思考，该题并不难，我们发现其实就是将链表的箭头顺序反转了，本质上就是 10←20←30←40←50，每一个指针都指向了之前的指针，所以我们只需要构造一个 previous 指针指向前一个节点即可

```
        public void reverse() {  
            //first second  
            //previous current  
            var previous = First;  
            var current = First.next;  
            Last = First;  
            Last.next = null;  
            while (current != null) {  
                var next = current.next;  
                current.next = previous;  
                previous = current;  
                current = next;  
            }  
            First = previous;  
        }  
    }
```

■

2.6 练习题 2: 寻找倒数第 K 个链表节点

■ **Example 2.2** 题目要求不允许直接遍历一整遍链表，然后获取对应的节点，我们使用快慢双指针来解决问题：快指针在一开始的时候就进行向前推进，当推进了 K 步之后慢指针开始运行，当快指针遍历完链表的时候，慢指针指向的节点就是对应的倒数第 K 个节点。

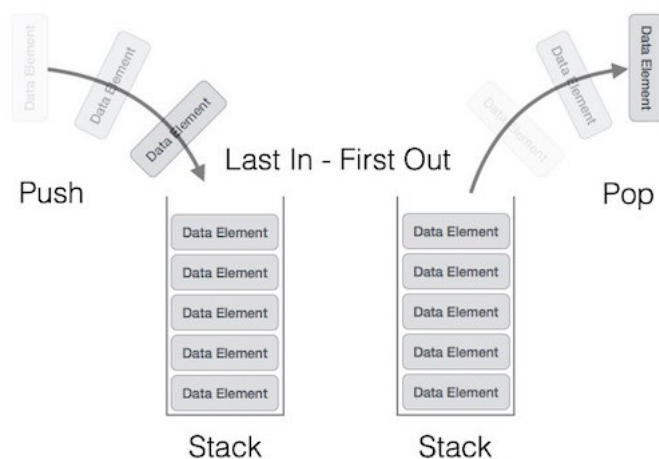
■

```
public int getKthFromTheEnd(int k) {  
    if (isEmpty()) {  
        throw new IllegalStateException();  
    }  
    if (k > size || k <= 0) {  
        throw new IllegalArgumentException();  
    }  
    //声明快指针  
    var a = First;  
    //声明慢指针  
    var b = First;  
    for (int i = 0; i < k - 1; i++) {  
        //先让 a 走 k 步  
        a = a.next;  
    }  
    while (a != Last) {  
        a = a.next;  
        b = b.next;  
    }  
    return b.value;  
}
```

3. Stack

3.1 Overview of Stack

栈是一种很常见的数据结构, 它遵循先入后出 (FILO) 的原则, 先入栈的元素反而最后出栈, 所以对于一些需要进行反转数据顺序的操作使用栈是非常适合的。



举一个非常通俗易懂的例子: 吃薯片。我们按照顺序向薯片口袋装入薯片, 先吃掉的反而是最后装入的薯片。还有 web 开发中的路由跳转, 每次跳转路由, 我们都将对应的路由压入栈中, 当我们要进行路由回退操作的时候, 回退的都是最后压入的路由

3.2 Stack in Java

在 Java 中有对应的 Stack 类型, 它主要的方法是 push 入栈, pop 出栈, peek 方法用于查看位于栈顶的元素, 但是不会弹出, empty 方法用于判断这个 stack 是否为空


```
Stack<Integer> stack = new Stack<>();
stack.push(1);
stack.push(2);
stack.push(3);
System.out.println(stack);//[1,2,3]
System.out.println(stack.pop());//3
System.out.println(stack.peek());//2
System.out.println(stack.empty());//false
```

3.3 MikeStack 的实现

MikeStack 的内部，我们使用数组来实现，但是使用数组来实现难免会出现一些问题。问题一：Java 实现的 Stack 不会出现栈满的问题，但是我们使用数组来实现，必然会会遇到数组元素占满，为了简便不对数组进行复制然后扩充，而是抛出一个异常状态。问题二：使用数组实现，在数组没有填满的时候，比如容量为 5，填充三个元素的时候，输出必然为 [1,2,3,0,0]，这样是不像 java 中栈的实现，所以我们使用一个 counter 计数器，只输出真正有值的部分。gg 对于 push,pop,peek 方法都需要进行临界情况的判定，如果 count==0 的时候，我们需要抛出一个 `IllegalStateException` 异常。

```
public class MikeStack {
    private final int[] array=new int[5];
    private int pointer=0;
}
```

```
public void push(int item){
    if(pointer>=array.length){
        throw new IllegalStateException();
    }
    array[pointer++]=item;
}
public int pop(){
    if(pointer==0){
        throw new IllegalStateException();
    }
    return array[--pointer];
}
public int peek(){
    if(pointer==0){
        throw new IllegalStateException();
    }
    return array[pointer-1];
}
public String toArray(){
    return Arrays.toString(Arrays.copyOfRange(array,0,pointer));
}
```

3.4 练习题 1: 反转字符串

■ **Example 3.1** 现在有一个字符串 Hello,World, 我们需要写一个方法来反转这个字符串。由于在前文中提过, 由于 Stack 的特性, 很容易进行一些反转操作, 所以我们使用 Stack 来完成这一题

```
public static String reverseString(String str){
    if(str==null){
        throw new IllegalArgumentException();
    }
    var stack=new Stack<Character>();
    for(char c :str.toCharArray()){
        stack.push(c);
    }
    StringBuilder stringBuilder=new StringBuilder("");
    while(!stack.empty()){
        stringBuilder.append(stack.pop());
    }
    return stringBuilder.toString();
}
```

从入栈到出栈就会导致数据以相反的顺序输出出来，所以我们只需要将数据压入栈中，最后再使用 pop 依次出栈即可。 ■

3.5 练习题 2: 判断表达式的平衡

■ **Example 3.2** 该题相较于上题来说，比较复杂。表达式中的符号有 {,(,<,[一共四种符号。

- {1+2+3} 平衡
- >1231< 不平衡
- <{1+2+3}> 平衡
- <{1+2}} 不平衡

一次性考虑所有的情况，比较复杂，所以我们首先考虑只有 () 的情况，遇到开始符号入栈，遇到结尾符号出栈，最后栈里是空的，那么就平衡。在考虑清楚单一情况之后，我们考虑所有的情况，可以将这些符号分别录入两个数组，但是一定要注意顺序对应，两个数组 AB,A[1] 和 B[1] 才是完全对应的。

```
public class Expression {
    private List<Character> leftBracket =
        Arrays.asList('(', '<', '[', '{');
    private List<Character> rightBracket =
        Arrays.asList(')', '>', ']', '}');
    String str;

    public Expression(String str) {
        this.str = str;
    }
    private boolean isLeftBracket(char c){
        return leftBracket.contains(c);
    }
    private boolean matchBracket(char left, char top){
        return leftBracket.indexOf(left)==rightBracket.indexOf(top);
    }
    private boolean isRightBracket(char c){
        return rightBracket.contains(c);
    }
    public boolean bBalancedEquation() {
        var stack = new Stack<Character>();
        for (char c : str.toCharArray()) {
            if (isLeftBracket(c)) {
                stack.push(c);
            }
            if (isRightBracket(c)) {
                if (stack.empty()) return false;
                char top = stack.pop();
                if (matchBracket(c,top)) {
                    return false;
                }
            }
        }
        return true;
    }
}
```




Part One Title

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4. Sectioning Examples

4.1 Section Title

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Unnumbered Section

Unnumbered Subsection

Unnumbered Subsubsection



5. In-text Element Examples

5.1 Referencing Publications

This statement requires citation [Smith:2022jd]; this one is more specific [Smith:2021qr].

5.2 Link Examples

This is a URL link: [LaTeX Templates](#). This is an email link: example@example.com.
This is a monospaced URL link: `https://www.LaTeXTemplates.com`.

5.3 Lists

Lists are useful to present information in a concise and/or ordered way.

5.3.1 Numbered List

1. First numbered item
 - a. First indented numbered item
 - b. Second indented numbered item
 - i. First second-level indented numbered item
2. Second numbered item
3. Third numbered item

5.3.2 Bullet Point List

- First bullet point item
 - First indented bullet point item
 - Second indented bullet point item
 - First second-level indented bullet point item
- Second bullet point item

- Third bullet point item

5.3.3 Descriptions and Definitions

Name Description

Word Definition

Comment Elaboration

5.4 International Support

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5.5 Ligatures

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Part Two Title

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6. Mathematics

6.1 Theorems

6.1.1 Several equations

This is a theorem consisting of several equations.

Theorem 6.1 — **Name of the theorem.** In $E = \mathbb{R}^n$ all norms are equivalent. It has the properties:

$$||\mathbf{x}|| - ||\mathbf{y}|| \leq ||\mathbf{x} - \mathbf{y}|| \quad (6.1)$$

$$||\sum_{i=1}^n \mathbf{x}_i|| \leq \sum_{i=1}^n ||\mathbf{x}_i|| \quad \text{where } n \text{ is a finite integer} \quad (6.2)$$

6.1.2 Single Line

This is a theorem consisting of just one line.

Theorem 6.2 A set $\mathcal{D}(G)$ is dense in $L^2(G)$, $|\cdot|_0$.

6.2 Definitions

A definition can be mathematical or it could define a concept.

Definition 6.1 — **Definition name.** Given a vector space E , a norm on E is an application, denoted $||\cdot||$, E in $\mathbb{R}^+ = [0, +\infty[$ such that:

$$||\mathbf{x}|| = 0 \Rightarrow \mathbf{x} = \mathbf{0} \quad (6.3)$$

$$||\lambda \mathbf{x}|| = |\lambda| \cdot ||\mathbf{x}|| \quad (6.4)$$

$$||\mathbf{x} + \mathbf{y}|| \leq ||\mathbf{x}|| + ||\mathbf{y}|| \quad (6.5)$$

6.3 Notations

■ **Notation 6.1** Given an open subset G of \mathbb{R}^n , the set of functions φ are:

1. Bounded support G ;
2. Infinitely differentiable;

a vector space is denoted by $\mathcal{D}(G)$.

6.4 Remarks

This is an example of a remark.



The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field $\mathbb{K} = \mathbb{R}$, however, established properties are easily extended to $\mathbb{K} = \mathbb{C}$.

6.5 Corollaries

Corollary 6.1 — Corollary name. The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field $\mathbb{K} = \mathbb{R}$, however, established properties are easily extended to $\mathbb{K} = \mathbb{C}$.

6.6 Propositions

6.6.1 Several equations

Proposition 6.1 — Proposition name. It has the properties:

$$||\mathbf{x}| - |\mathbf{y}|| \leq |\mathbf{x} - \mathbf{y}| \quad (6.6)$$

$$||\sum_{i=1}^n \mathbf{x}_i|| \leq \sum_{i=1}^n ||\mathbf{x}_i|| \quad \text{where } n \text{ is a finite integer} \quad (6.7)$$

6.6.2 Single Line

Proposition 6.2 Let $f, g \in L^2(G)$; if $\forall \varphi \in \mathcal{D}(G)$, $(f, \varphi)_0 = (g, \varphi)_0$ then $f = g$.

6.7 Examples

6.7.1 Equation Example

■ **Example 6.1** Let $G = \{x \in \mathbb{R}^2 : |x| < 3\}$ and denoted by: $x^0 = (1, 1)$; consider the function:

$$f(x) = \begin{cases} e^{|x|} & \text{si } |x - x^0| \leq 1/2 \\ 0 & \text{si } |x - x^0| > 1/2 \end{cases} \quad (6.8)$$

The function f has bounded support, we can take $A = \{x \in \mathbb{R}^2 : |x - x^0| \leq 1/2 + \varepsilon\}$ for all $\varepsilon \in]0; 5/2 - \sqrt{2}[$. ■

6.7.2 Text Example

■ **Example 6.2 — Example name.** Aliquam arcu turpis, ultrices sed luctus ac, vehicula id metus. Morbi eu feugiat velit, et tempus augue. Proin ac mattis tortor. Donec tincidunt, ante rhoncus luctus semper, arcu lorem lobortis justo, nec convallis ante quam quis lectus. Aenean tincidunt sodales massa, et hendrerit tellus mattis ac. Sed non pretium nibh. Donec cursus maximus luctus. Vivamus lobortis eros et massa porta porttitor. ■

6.8 Exercises

Exercise 6.1 This is a good place to ask a question to test learning progress or further cement ideas into students' minds. ■

6.9 Problems

Problem 6.1 What is the average airspeed velocity of an unladen swallow?

6.10 Vocabulary

Define a word to improve a students' vocabulary.

■ **Vocabulary 6.1 — Word.** Definition of word.



7. Presenting Information and Results with a Long Chapter Title

7.1 Table

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Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

表 7.1: Table caption.

Referencing Table 7.1 in-text using its label.

7.2 Figure

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Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

表 7.2: Floating table.



图 7.1: Figure caption.

Referencing Figure 7.1 in-text using its label.



图 7.2: Floating figure.

Bibliography

Articles

Books



A. Appendix Chapter Title

A.1 Appendix Section Title

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B. Appendix Chapter Title

B.1 Appendix Section Title

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