UNIVERSITÄT BERN

Linear Data Structures

Lecturer: **Nataliia Stulova**
Teaching assistant: **Mohammadreza Hazirprasand**

MASTER IN COMPUTER SCIENCE
OF THE UNIVERSITIES OF BERN, NEUCHÂTEL AND FRIBOURG

Software Skills Lab

Linear data structures

Arrays
Lists
Stacks
Queues

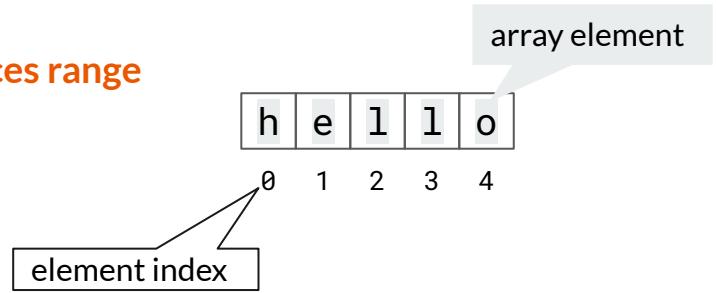
- They are abstractions of all kinds of rows, sequences, and series from the real world...
- ... so their elements are arranged sequentially or linearly and linked one after another in a specified order

Arrays

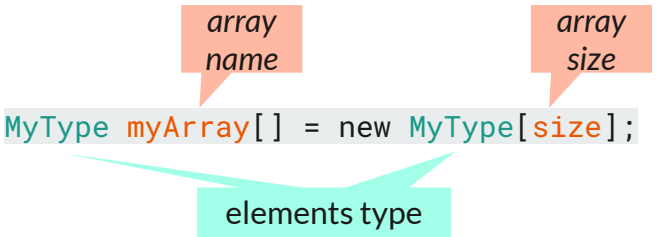
Array data structure

- a native data structure to store a fixed number of elements of the same type
- elements are accessed by their relative position (***random access***) - each element is independent of others

N-elements array indices range from `0` to `N-1`



Java arrays




```
MyType myArray[];
myArray = new MyType[size];
```

On creation arrays of *primitive* types are filled with ***default values***:

```
boolean status[];
status = new boolean[2];
```

false	false
0	1

```
status[0] = true;
```

true	false
0	1

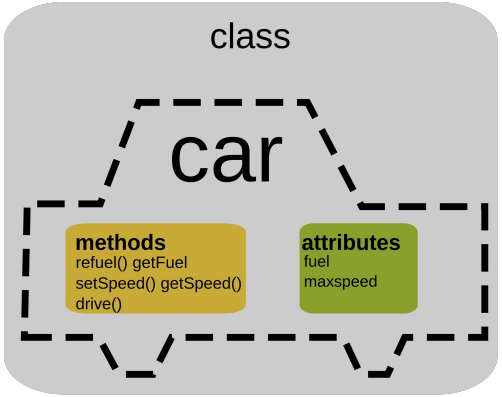
Creating Java arrays

Arrays of primitive types

```
int nums[] = new int[2];

nums[0] = 23;
nums[1] = 9;

int nums[] = {23, 9};
```

Arrays of objects

```
Car parking[] = new Car[20];

parking[0] = new Car();
parking[0].setSpeed(0);

Car truck = new Car();
truck.fuel = 20;
parking[1] = truck;
```



Multi-dimensional arrays

Multidimensional arrays are **arrays of arrays** with each element of the array holding the reference of other array

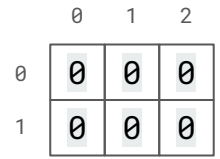
```
MyType matrix[]..[] = new MyType[s1]..[sN];
```

number of dimensions

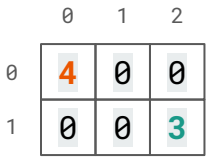
each dimension size

rows *columns*

```
int matrix[][] = new int[2][3];
```




```
matrix[0][0] = 4;
matrix[1][2] = 3;
```



Examples: spreadsheets, games (like sudoku), timetables, images

java.util.Arrays

Reference Javadoc: **Arrays (Java SE 11 & JDK 11)**

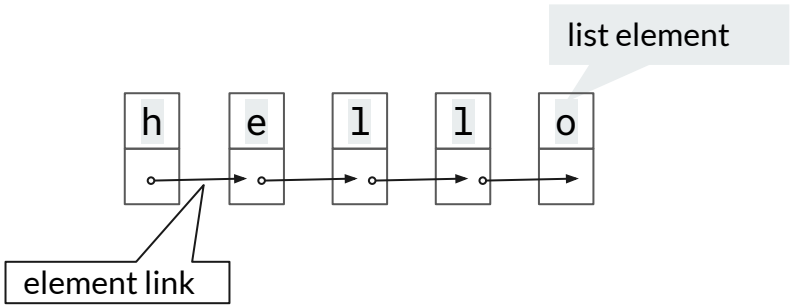
This class contains various methods for manipulating arrays (such as sorting and searching):

- `fill()`
- `sort()` (last lecture)
- `binarySearch()` (last lecture)
- `copyOf()`
- `equals()`
- `...`

Lists

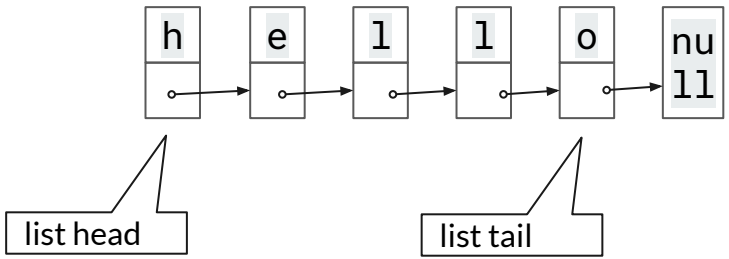
Linked list data structure

- a data structure to store a *non*-fixed number of elements of the same type
- elements are accessed in their order (***sequential access***) - each element needs to be connected to the previous



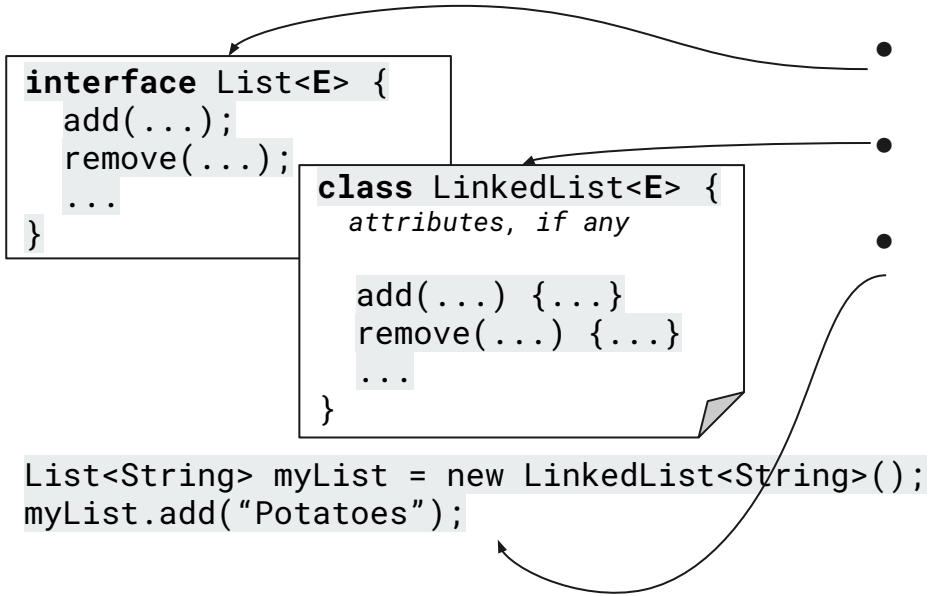
Linked list in Java from scratch

implementing a linked list data structure from scratch in Java can involve Nested Classes - a a way of logically grouping classes that are only used in one place




```
public class LinkedList<T> {

   //Node inner class
   public class Node {
      public T data;         //Data to store
      public Node nextNode; //Link to next node
   }

   //head node
   public Node headNode;

   ...

}
```

Java lists: Classes VS Interfaces



- `List<E>` is an ***Interface*** - a blueprint of a class, does not hold any implementation details
- `LinkedList<E>` is a **Class** - a blueprint of an object, has attributes and methods, does not hold any values
- `myList` is an **Object** - an instance of the `LinkedList<E>` class, holds concrete values in its attributes

Accessing list elements

```
List<String> groceries = Arrays.asList("Potatoes", "Ketchup", "Eggs");
```

Iterators new

An interface to go through elements in a collection data structure:

- `hasNext()` method checks if there are any elements remaining in the list
- `next()` method returns the next element in the iteration

```
Iterator<String> groceriesIterator = groceries.iterator();

while(groceriesIterator.hasNext()) {
      System.out.println(groceriesIterator.next());
}
```

Loops

```
for (int i = 0; i < groceries.size(); i++) {
      System.out.println(groceries.get(i));
    }

for (String product : groceries) {
      System.out.println(product);
    }
```

java.util.List

Reference Javadoc: List (Java SE 11 & JDK 11)

Some **classes** implementing the `List` interface:

LinkedList (Java SE 11 & JDK 11)

ArrayList (Java SE 11 & JDK 11)

Vector (Java SE 11 & JDK 11)

Differences:memory management, element access (some allow random access), allowing or not `null` elements,...

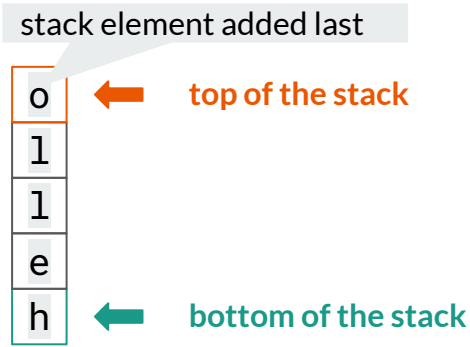
A library **interface** that provides various useful operations on lists:

- **`get()`**
- **`add()`**, `addAll()`
- **`remove()`**
- `contains()`, `containsAll()`
- `clone()`
- `equals()`
- `...`

Stacks

Stack data structure

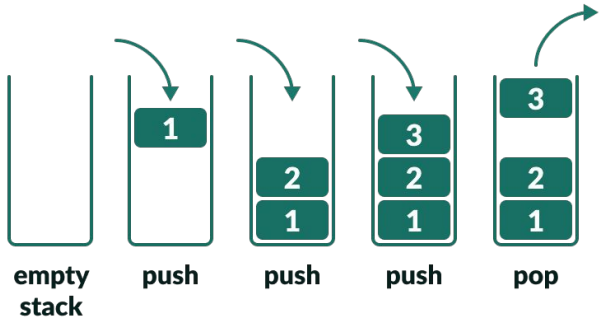
- a data structure to store a *non*-fixed number of elements of the same type
- elements are stored sequentially, but accessed by the **Last In First Out (LIFO)** principle, one at a time, at the top of the stack



Stack operations

Basic:

- **push**: add an element to the top of the stack
- **pop**: remove an element from the top of the stack and return it



Extra:

- **top**/**peek**: get the value of the top element of the stack without removing the element
- checks for emptiness and fullness

Stack implementation and use

Some examples of use

- an “undo” mechanism in text editors
- forward and backward navigation in web browsers
- expression parsing and evaluation (e.g.,)
- memory management (part II of this course)

Implementations

- array-based, esp. with fixed capacity
- as a resizable array (e.g., using a `Vector`)
- linked list-based

java.util.Stack<E>

Reference Javadoc: Stack (Java SE 11 & JDK 11)

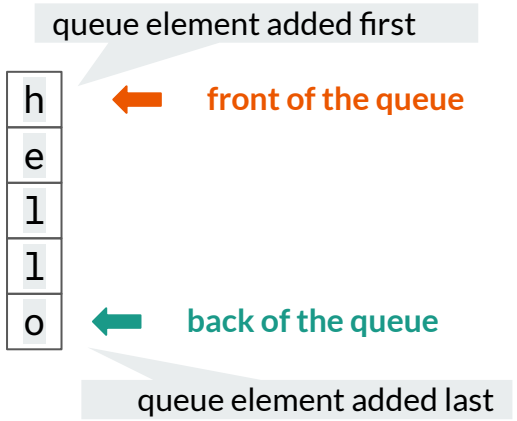
The Stack **class** represents a last-in-first-out (LIFO) stack of objects.

- `empty()`
- `peek()`
- `pop()`
- `push(E item)`
- `search(Object obj)`

Queues

Queue data structure

- a data structure to store a *non*-fixed number of elements of the same type
- elements are stored sequentially, but accessed by the **First In First Out (FIFO)** principle, one at a time, at the top of the stack



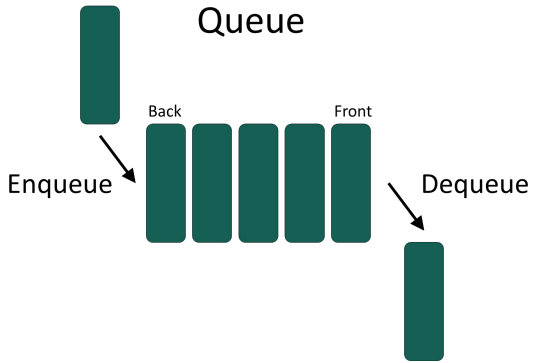
Queue operations

Basic:

- **enqueue**: add an element to the back of the queue
- **dequeue**: remove an element from the front of the queue and return it

Extra:

- **front**: get the value of the first element of the queue without removing the element
- checks for emptiness and fullness



Queue implementation and use

Some examples of use

- handling of high-priority processes in an operating system is handled using queues
- ordering requests to a printer to print pages, the requests are handled by using a queue
- messages on social media, they are sent to a queue on the server

Implementations

- array-based, esp. with fixed capacity
- linked list-based

java.util.Queue<E>

Reference Javadoc: Queue (Java SE 11 & JDK 11)

A library **interface** that provides various queue operations:

Summary of Queue methods

	Throws exception	*Returns special value*
Insert	`add(e)`	`offer(e)`
Remove	`remove()`	`poll()`
Examine	`element()`	`peek()`

What you should remember

Use arrays when:

- you know the number of elements…
- … or the number of elements will increase rarely
- you need fast access to individual elements

Use lists when:

- you do not know the number of elements
- you do not need fast access to individual elements

Summary and practice

new **`this`** keyword: clarify the context

```
result[i][j] = this.matrix[i][j] + other.matrix[i][j]
```

Exercise 1: Arrays

Matrix multiplication

- write a class representing a 2D matrix
- attributes:
  - `int matrix[][]`
- methods:
  - `Matrix(int rows, int cols)` - constructor
  - `Matrix add(Matrix other)` - addition
  - `Matrix product(Matrix other)` - multiplication

https://en.wikipedia.org/wiki/Matrix_(mathematics)#Basic_operations

I/O

-

Tests (JUnit, class MatrixTest)

- dimensions mismatch
- 3 correct cases: 1-column matrix, 1-row matrix, a 2x3 matrix

new `static` keyword: helper methods (and no objects!)

```
Double arMean = Averages.artihMean(ArrayList<E> nums)
```

new boxed types: Integer, Float, Double….

Exercise 2: Lists

Computing various average values

- write a class `Averages` to compute various means: arithmetic, geometric, and harmonic
  https://en.wikipedia.org/wiki/Average
- methods:
  - `static Double arithMean(ArrayList<E> nums)`
  - `static Double geomMean(ArrayList<E> nums)`
  - `static Double harmMean(ArrayList<E> nums)`

I/O

- Read a sequence of numbers from `System.in`
- Print average values to `System.out`

Tests

- one test for each method