Sirf khwabh Nhi

30/08

1]Inheritance

Java inheritance and its types with the help of example.

Inheritance is one of the key features of OOP that allows us to create a new class from an existing class.

The new class that is created is known as subclass (child or derived class) and the existing class from where the child class is derived is known as superclass (parent or base class).

The `extends` keyword is used to perform inheritance in Java. For example,

```
class Animal {

  // methods and fields

}



// use of extends keyword

// to perform inheritance

class Dog extends Animal {



  // methods and fields of Animal

  // methods and fields of Dog

}
```

In the above example, the `Dog` class is created by inheriting the methods and fields from the `Animal` class.

Here, `Dog` is the subclass and `Animal` is the superclass.

Example 1: Java Inheritance

```
class Animal {


  // field and method of the parent class

  String name;

  public void eat() {

    System.out.println("I can eat");

  }

}


// inherit from Animal

class Dog extends Animal {


  // new method in subclass

  public void display() {

    System.out.println("My name is " + name);

  }

}


class Main {

  public static void main(String[] args) {
    // create an object of the subclass

    Dog labrador = new Dog();



    // access field of superclass

    labrador.name = "Rohu";

    labrador.display();



    // call method of superclass

    // using object of subclass

    labrador.eat();



  }

}
```

Output

```
My name is Rohu

I can eat
```

In the above example, we have derived a subclass `Dog` from superclass `Animal`. Notice the statements,

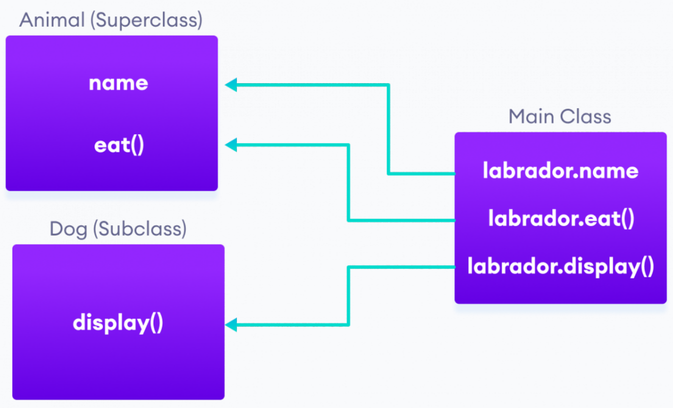
```
labrador.name = "Rohu";



labrador.eat();
```

Here, `labrador` is an object of `Dog`. However, `name` and `eat()` are the members of the `Animal` class.

Since `Dog` inherits the field and method from `Animal`, we are able to access the field and method using the object of the `Dog`.



Java Inheritance Implementation

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is-a relationship

In Java, inheritance is an is-a relationship. That is, we use inheritance only if there exists an is-a relationship between two classes. For example,

- Car is a Vehicle
- Orange is a Fruit
- Surgeon is a Doctor
- Dog is an Animal

Here, Car can inherit from Vehicle, Orange can inherit from Fruit, and so on.

Method Overriding in Java Inheritance

In Example 1, we see the object of the subclass can access the method of the superclass.

However, if the same method is present in both the superclass and subclass, what will happen?

In this case, the method in the subclass overrides the method in the superclass. This concept is known as method overriding in Java.

Example 2: Method overriding in Java Inheritance

```
class Animal {


  // method in the superclass

  public void eat() {

    System.out.println("I can eat");

  }

}


// Dog inherits Animal

class Dog extends Animal {


  // overriding the eat() method

  @Override

  public void eat() {

    System.out.println("I eat dog food");

  }


  // new method in subclass

  public void bark() {

    System.out.println("I can bark");

  }

}
```

```
class Main {

  public static void main(String[] args) {



    // create an object of the subclass

    Dog labrador = new Dog();



    // call the eat() method

    labrador.eat();

    labrador.bark();

  }

}
```

Output

```
I eat dog food

I can bark
```

In the above example, the `eat()` method is present in both the superclass `Animal` and the subclass `Dog`.

Here, we have created an object `labrador` of `Dog`.

Now when we call `eat()` using the object `labrador`, the method inside `Dog` is called. This is because the method inside the derived class overrides the method inside the base class.

Note: We have used the `@Override` annotation to tell the compiler that we are overriding a method. However, the annotation is not mandatory.

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super Keyword in Java Inheritance

Previously we saw that the same method in the subclass overrides the method in superclass.

In such a situation, the `super` keyword is used to call the method of the parent class from the method of the child class.

Example 3: super Keyword in Inheritance

```
class Animal {


  // method in the superclass

  public void eat() {

    System.out.println("I can eat");

  }

}


// Dog inherits Animal

class Dog extends Animal {


  // overriding the eat() method

  @Override

  public void eat() {


    // call method of superclass

    super.eat();

    System.out.println("I eat dog food");

  }
  // new method in subclass

  public void bark() {

    System.out.println("I can bark");

  }

}



class Main {

  public static void main(String[] args) {



    // create an object of the subclass

    Dog labrador = new Dog();



    // call the eat() method

    labrador.eat();

    labrador.bark();

  }

}
```

Output

```
I can eat

I eat dog food

I can bark
```

In the above example, the `eat()` method is present in both the base class `Animal` and the derived class `Dog`. Notice the statement,

```
super.eat();
```

Here, the `super` keyword is used to call the `eat()` method present in the superclass.

We can also use the `super` keyword to call the constructor of the superclass from the constructor of the subclass.

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protected Members in Inheritance

In Java, if a class includes `protected` fields and methods, then these fields and methods are accessible from the subclass of the class.

Example 4: protected Members in Inheritance

```
class Animal {
  protected String name;


  protected void display() {
    System.out.println("I am an animal.");
  }
}


class Dog extends Animal {


  public void getInfo() {
    System.out.println("My name is " + name);
  }
}



class Main {

  public static void main(String[] args) {



    // create an object of the subclass

    Dog labrador = new Dog();



    // access protected field and method

    // using the object of subclass

    labrador.name = "Rocky";

    labrador.display();



    labrador.getInfo();

  }

}
```

Output

```
I am an animal.

My name is Rocky
```

In the above example, we have created a class named Animal. The class includes a protected field: `name` and a method: `display()`.

We have inherited the `Dog` class inherits `Animal`. Notice the statement,

```
labrador.name = "Rocky";
labrador.display();
```

Here, we are able to access the protected field and method of the superclass using the `labrador` object of the subclass.

Why use inheritance?

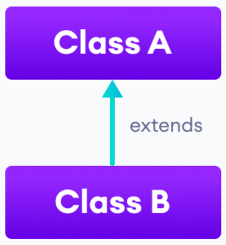
- **The most important use of inheritance in Java is code reusability. The code that is present in the parent class can be directly used by the child class.**
- **Method overriding is also known as runtime polymorphism. Hence, we can achieve Polymorphism in Java with the help of inheritance.**

Types of inheritance

There are five types of inheritance.

1. Single Inheritance

In single inheritance, a single subclass extends from a single superclass. For example,



Java Single Inheritance

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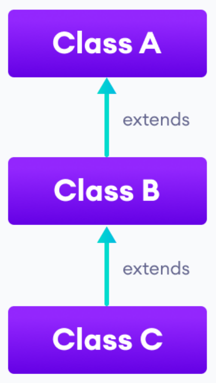
2. Multilevel Inheritance

In multilevel inheritance, a subclass extends from a superclass and then the same subclass acts as a superclass for another class. For example,



Java Multilevel Inheritance

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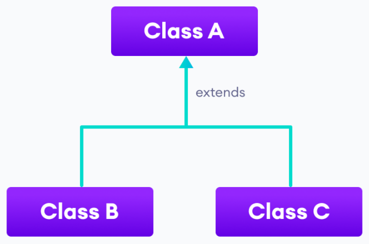
3. Hierarchical Inheritance

In hierarchical inheritance, multiple subclasses extend from a single superclass. For example,



Java Hierarchical Inheritance

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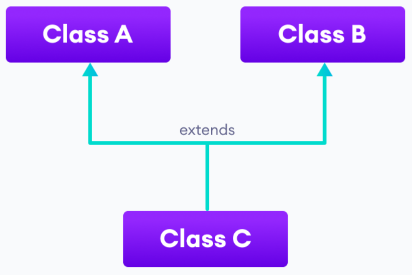
4. Multiple Inheritance

In multiple inheritance, a single subclass extends from multiple superclasses. For example,

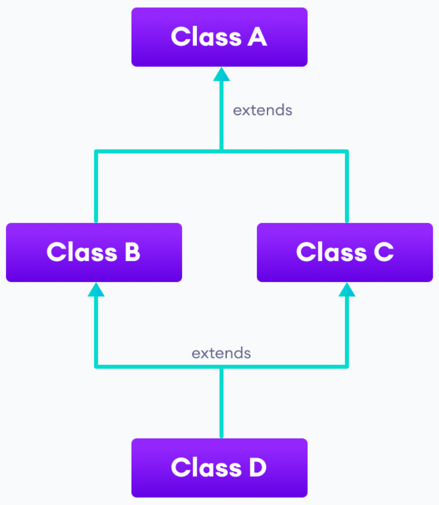


Java Multiple Inheritance

> Note: Java doesn't support multiple inheritance. However, we can achieve multiple inheritance using interfaces.

5. Hybrid Inheritance

Hybrid inheritance is a combination of two or more types of inheritance. For example,



Java Hybrid Inheritance

Here, we have combined hierarchical and multiple inheritance to form a hybrid inheritance.

2]Java Method Overriding

we will learn about method overriding in Java with the help of examples.

we learned about inheritance. Inheritance is an OOP property that allows us to derive a new class (subclass) from an existing class (superclass). The subclass inherits the attributes and methods of the superclass.

Now, if the same method is defined in both the superclass and the subclass, then the method of the subclass class overrides the method of the superclass. This is known as method overriding.

Example 1: Method Overriding

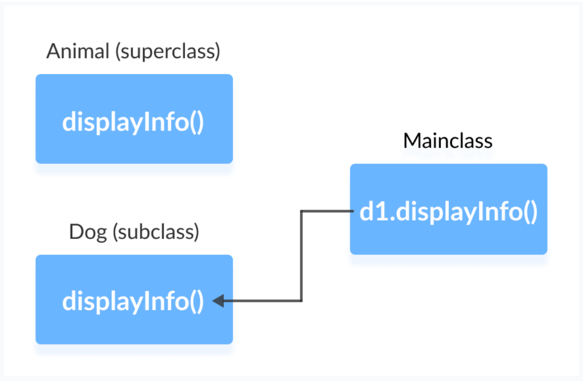
```
class Animal {

   public void displayInfo() {

      System.out.println("I am an animal.");

   }
}

class Dog extends Animal {
    @Override
    public void displayInfo() {
        System.out.println("I am a dog.");
    }
}

class Main {
    public static void main(String[] args) {
        Dog d1 = new Dog();
        d1.displayInfo();
    }
}
```

Output:

```
I am a dog.
```

In the above program, the `displayInfo()` method is present in both the `Animal` superclass and the `Dog` subclass.

When we call `displayInfo()` using the `d1` object (object of the subclass), the method inside the subclass `Dog` is called. The `displayInfo()` method of the subclass overrides the same method of the superclass.



Notice the use of the `@Override` annotation in our example. In Java, annotations are the metadata that we used to provide information to the compiler. Here, the `@Override` annotation specifies the compiler that the method after this annotation overrides the method of the superclass.

It is not mandatory to use `@Override`. However, when we use this, the method should follow all the rules of overriding. Otherwise, the compiler will generate an error.

Java Overriding Rules

- Both the superclass and the subclass must have the same method name, the same return type and the same parameter list.
- We cannot override the method declared as `final` and `static`.
- We should always override abstract methods of the superclass (will be discussed in later tutorials).

---

super Keyword in Java Overriding

A common question that arises while performing overriding in Java is:

Can we access the method of the superclass after overriding?

Well, the answer is Yes. To access the method of the superclass from the subclass, we use the `super` keyword.

Example 2: Use of super Keyword

```
class Animal {

   public void displayInfo() {
        System.out.println("I am an animal.");
    }
}

class Dog extends Animal {
    public void displayInfo() {
        super.displayInfo();
        System.out.println("I am a dog.");
    }
}

class Main {
    public static void main(String[] args) {
        Dog d1 = new Dog();
        d1.displayInfo();
    }
}
```

Output:

```
I am an animal.
I am a dog.
```

In the above example, the subclass `Dog` overrides the method `displayInfo()` of the superclass `Animal`.

When we call the method `displayInfo()` using the `d1` object of the `Dog` subclass, the method inside the `Dog` subclass is called; the method inside the superclass is not called.

Inside `displayInfo()` of the `Dog` subclass, we have used `super.displayInfo()` to call `displayInfo()` of the superclass.

It is important to note that constructors in Java are not inherited. Hence, there is no such thing as constructor overriding in Java.

However, we can call the constructor of the superclass from its subclasses. For that, we use `super()`.

Access Specifiers in Method Overriding

The same method declared in the superclass and its subclasses can have different access specifiers. However, there is a restriction.

We can only use those access specifiers in subclasses that provide larger access than the access specifier of the superclass. For example,

Suppose, a method `myClass()` in the superclass is declared `protected`. Then, the same method `myClass()` in the subclass can be either `public` or `protected`, but not `private`.

Example 3: Access Specifier in Overriding

```
class Animal {

   protected void displayInfo() {

      System.out.println("I am an animal.");

   }

}
```

```
class Dog extends Animal {

    public void displayInfo() {

        System.out.println("I am a dog.");

    }

}


class Main {

    public static void main(String[] args) {

        Dog d1 = new Dog();

        d1.displayInfo();

    }

}
```

Output:

```
I am a dog.
```

In the above example, the subclass `Dog` overrides the method `displayInfo()` of the superclass `Animal`.

Whenever we call `displayInfo()` using the `d1` (object of the subclass), the method inside the subclass is called.

Notice that, the `displayInfo()` is declared `protected` in the `Animal` superclass. The same method has the `public` access specifier in the `Dog` subclass. This is possible because the `public` provides larger access than the `protected`.

Overriding Abstract Methods

In Java, abstract classes are created to be the superclass of other classes. And, if a class contains an abstract method, it is mandatory to override it.

3)Java super

we will learn about the super keyword in Java with the help of examples.

The `super` keyword in Java is used in subclasses to access superclass members (attributes, constructors and methods).

Before we learn about the `super` keyword, make sure to know about Java inheritance.

Uses of super keyword

1. To call methods of the superclass that is overridden in the subclass.
2. To access attributes (fields) of the superclass if both superclass and subclass have attributes with the same name.
3. To explicitly call superclass no-arg (default) or parameterized constructor from the subclass constructor.

Let’s understand each of these uses.

---

1. Access Overridden Methods of the superclass

If methods with the same name are defined in both superclass and subclass, the method in the subclass overrides the method in the superclass. This is called method overriding.

Example 1: Method overriding

```
class Animal {
  // overridden method

  public void display(){

    System.out.println("I am an animal");

  }

}



class Dog extends Animal {



  // overriding method

  @Override

  public void display(){

    System.out.println("I am a dog");

  }



  public void printMessage(){

    display();

  }

}



class Main {

  public static void main(String[] args) {

    Dog dog1 = new Dog();

    dog1.printMessage();
    }
```

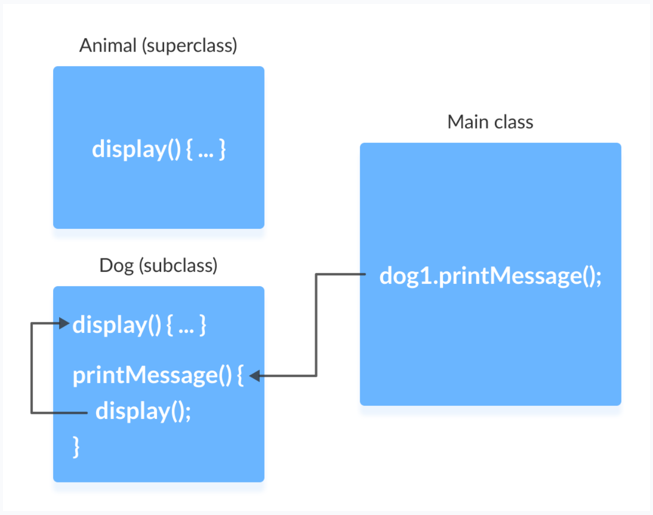
```
}
```

Output

```
I am a dog
```

In this example, by making an object `dog1` of `Dog` class, we can call its method `printMessage()` which then executes the `display()` statement.

Since `display()` is defined in both the classes, the method of subclass `Dog` overrides the method of superclass `Animal`. Hence, the `display()` of the subclass is called.



What if the overridden method of the superclass has to be called?

We use `super.display()` if the overridden method `display()` of superclass `Animal` needs to be called.

Example 2: super to Call Superclass Method

```
class Animal {
```

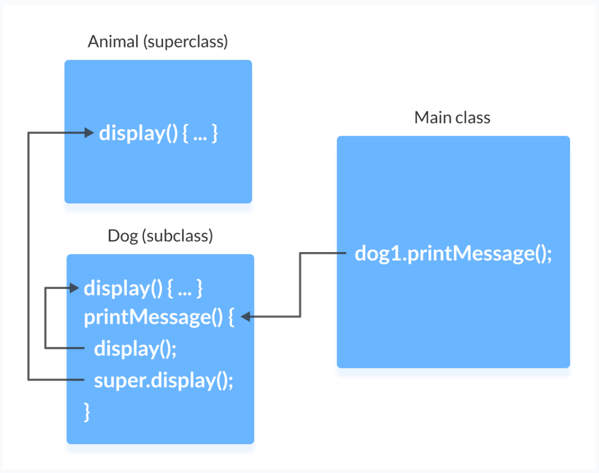
```
  // overridden method
  public void display(){

    System.out.println("I am an animal");

  }

}



class Dog extends Animal {



  // overriding method

  @Override

  public void display(){

    System.out.println("I am a dog");

  }



  public void printMessage(){



    // this calls overriding method

    display();



    // this calls overridden method

    super.display();

  }

}
```

```
class Main {

  public static void main(String[] args) {

    Dog dog1 = new Dog();

    dog1.printMessage();

  }

}
```

Output

```
I am a dog

I am an animal
```

Here, how the above program works.



2. Access Attributes of the Superclass

The superclass and subclass can have attributes with the same name. We use the `super` keyword to access the attribute of the superclass.

Example 3: Access superclass attribute

```
class Animal {
  protected String type="animal";

}



class Dog extends Animal {

  public String type="mammal";



  public void printType() {

    System.out.println("I am a " + type);

    System.out.println("I am an " + super.type);

  }

}



class Main {

  public static void main(String[] args) {

    Dog dog1 = new Dog();

    dog1.printType();

  }

}
```

Output:

```
I am a mammal

I am an animal
```

In this example, we have defined the same instance field `type` in both the superclass `Animal` and the subclass `Dog`.

We then created an object `dog1` of the `Dog` class. Then, the `printType()` method is called using this object.

Inside the `printType()` function,

- `type` refers to the attribute of the subclass `Dog`.
- `super.type` refers to the attribute of the superclass Animal.

Hence, `System.out.println("I am a " + type);` prints `I am a mammal`. And, `System.out.println("I am an " + super.type);` prints `I am an animal`.

---

3. Use of super() to access superclass constructor

As we know, when an object of a class is created, its default constructor is automatically called.

To explicitly call the superclass constructor from the subclass constructor, we use `super()`. It's a special form of the `super` keyword.

`super()` can be used only inside the subclass constructor and must be the first statement.

Example 4: Use of super()

```
class Animal {


  // default or no-arg constructor of class Animal

  Animal() {

    System.out.println("I am an animal");

  }

}
```

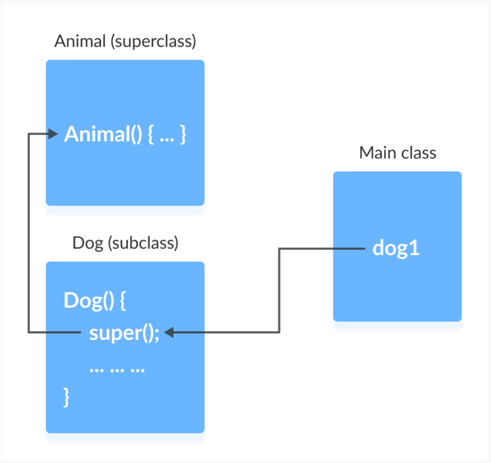
```
class Dog extends Animal {

  // default or no-arg constructor of class Dog
  Dog() {

    // calling default constructor of the superclass
    super();

    System.out.println("I am a dog");
  }
}

class Main {
  public static void main(String[] args) {
    Dog dog1 = new Dog();
  }
}
```

Output

```
I am an animal
I am a dog
```

Here, when an object `dog1` of `Dog` class is created, it automatically calls the default or no-arg constructor of that class.

Inside the subclass constructor, the `super()` statement calls the constructor of the superclass and executes the statements inside it. Hence, we get the output `I am an animal`.



The flow of the program then returns back to the subclass constructor and executes the remaining statements. Thus, `I am a dog` will be printed.

However, using `super()` is not compulsory. Even if `super()` is not used in the subclass constructor, the compiler implicitly calls the default constructor of the superclass.

So, why use redundant code if the compiler automatically invokes super()?

It is required if the parameterized constructor (a constructor that takes arguments) of the superclass has to be called from the subclass constructor.

The parameterized `super()` must always be the first statement in the body of the constructor of the subclass, otherwise, we get a compilation error.

Example 5: Call Parameterized Constructor Using super()

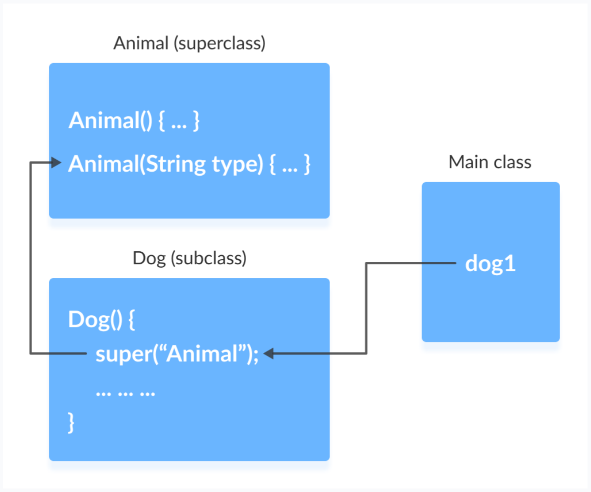
```
class Animal {



  // default or no-arg constructor

  Animal() {

    System.out.println("I am an animal");
    }

    // parameterized constructor
    Animal(String type) {
        System.out.println("Type: "+type);
    }
}

class Dog extends Animal {

    // default constructor
    Dog() {

        // calling parameterized constructor of the superclass
        super("Animal");

        System.out.println("I am a dog");
    }
}

class Main {
    public static void main(String[] args) {
        Dog dog1 = new Dog();
    }
}
```

Output

```
Type: Animal
I am a dog
```

The compiler can automatically call the no-arg constructor. However, it cannot call parameterized constructors.

If a parameterized constructor has to be called, we need to explicitly define it in the subclass constructor.



Note that in the above example, we explicitly called the parameterized constructor `super("Animal")`. The compiler does not call the default constructor of the superclass in this case.

4)Java Abstract Class and Abstract Methods

Java abstract classes and methods with the help of examples. We will also learn about abstraction in Java.

Java Abstract Class

The abstract class in Java cannot be instantiated (we cannot create objects of abstract classes). We use the `abstract` keyword to declare an abstract class. For example,

```
// create an abstract class

abstract class Language {

  // fields and methods

}

...



// try to create an object Language

// throws an error

Language obj = new Language();
```

An abstract class can have both the regular methods and abstract methods. For example,

```
abstract class Language {



  // abstract method

  abstract void method1();



  // regular method
  void method2() {

    System.out.println("This is regular method");

  }

}
```

Java Abstract Method

A method that doesn't have its body is known as an abstract method. We use the same `abstract` keyword to create abstract methods. For example,

```
abstract void display();
```

Here, `display()` is an abstract method. The body of `display()` is replaced by `;`.

If a class contains an abstract method, then the class should be declared abstract. Otherwise, it will generate an error. For example,

```
// error

// class should be abstract

class Language {



  // abstract method

  abstract void method1();

}
```

Example: Java Abstract Class and Method

Though abstract classes cannot be instantiated, we can create subclasses from it. We can then access members of the abstract class using the object of the subclass. For example,

```
abstract class Language {
  // method of abstract class

  public void display() {

    System.out.println("This is Java Programming");

  }

}



class Main extends Language {



  public static void main(String[] args) {



    // create an object of Main

    Main obj = new Main();



    // access method of abstract class

    // using object of Main class

    obj.display();

  }

}
```

Output

```
This is Java programming
```

In the above example, we have created an abstract class named `Language`. The class contains a regular method `display()`.

We have created the Main class that inherits the abstract class. Notice the statement,

```
obj.display();
```

Here, `obj` is the object of the child class `Main`. We are calling the method of the abstract class using the object `obj`.

Implementing Abstract Methods

If the abstract class includes any abstract method, then all the child classes inherited from the abstract superclass must provide the implementation of the abstract method. For example,

```
abstract class Animal {
  abstract void makeSound();

  public void eat() {
    System.out.println("I can eat.");
  }
}

class Dog extends Animal {

  // provide implementation of abstract method
  public void makeSound() {
    System.out.println("Bark bark");
  }
}
```

```
class Main {

  public static void main(String[] args) {



    // create an object of Dog class

    Dog d1 = new Dog();



    d1.makeSound();

    d1.eat();

  }

}
```

Output

```
Bark bark

I can eat.
```

In the above example, we have created an abstract class `Animal`. The class contains an abstract method `makeSound()` and a non-abstract method `eat()`.

We have inherited a subclass `Dog` from the superclass `Animal`. Here, the subclass `Dog` provides the implementation for the abstract method `makeSound()`.

We then used the object `d1` of the `Dog` class to call methods `makeSound()` and `eat()`.

> Note: If the `Dog` class doesn't provide the implementation of the abstract method `makeSound()`, `Dog` should also be declared as abstract. This is because the subclass `Dog` inherits `makeSound()` from `Animal`.

Accesses Constructor of Abstract Classes

An abstract class can have constructors like the regular class. And, we can access the constructor of an abstract class from the subclass using the `super` keyword. For example,

```
abstract class Animal {

    Animal() {

          ….

    }

}



class Dog extends Animal {

    Dog() {

          super();

          ...

    }

}
```

Here, we have used the `super()` inside the constructor of `Dog` to access the constructor of the `Animal`.

Note that the `super` should always be the first statement of the subclass constructor.

Java Abstraction

The major use of abstract classes and methods is to achieve abstraction in Java.

Abstraction is an important concept of object-oriented programming that allows us to hide unnecessary details and only show the needed information.

This allows us to manage complexity by omitting or hiding details with a simpler, higher-level idea.

A practical example of abstraction can be motorbike brakes. We know what brake does. When we apply the brake, the motorbike will stop. However, the working of the brake is kept hidden from us.

The major advantage of hiding the working of the brake is that now the manufacturer can implement brake differently for different motorbikes, however, what brake does will be the same.

Let's take an example that helps us to better understand Java abstraction.

Example 3: Java Abstraction

```
abstract class MotorBike {

  abstract void brake();

}



class SportsBike extends MotorBike {



  // implementation of abstract method

  public void brake() {

    System.out.println("SportsBike Brake");

  }

}



class MountainBike extends MotorBike {



  // implementation of abstract method

  public void brake() {

    System.out.println("MountainBike Brake");

  }
}

class Main {

  public static void main(String[] args) {

    MountainBike m1 = new MountainBike();

    m1.brake();

    SportsBike s1 = new SportsBike();

    s1.brake();

  }

}
```

Output:

```
MountainBike Brake

SportsBike Brake
```

In the above example, we have created an abstract super class `MotorBike`. The superclass `MotorBike` has an abstract method `brake()`.

The `brake()` method cannot be implemented inside `MotorBike`. It is because every bike has different implementation of brakes. So, all the subclasses of `MotorBike` would have different implementation of `brake()`.

So, the implementation of `brake()` in `MotorBike` is kept hidden.

Here, `MountainBike` makes its own implementation of `brake()` and `SportsBike` makes its own implementation of `brake()`.

Note: We can also use interfaces to achieve abstraction in Java.

Key Points to Remember

- We use the `abstract` keyword to create abstract classes and methods.
- An abstract method doesn't have any implementation (method body).
- A class containing abstract methods should also be abstract.
- We cannot create objects of an abstract class.
- To implement features of an abstract class, we inherit subclasses from it and create objects of the subclass.
- A subclass must override all abstract methods of an abstract class. However, if the subclass is declared abstract, it's not mandatory to override abstract methods.
- We can access the static attributes and methods of an abstract class using the reference of the abstract class. For example,
  ```
  Animal.staticMethod();
  ```

5) Java Interface

we will learn about Java interfaces. We will learn how to implement interfaces and when to use them in detail with the help of examples.

An interface is a fully abstract class. It includes a group of abstract methods (methods without a body).

We use the `interface` keyword to create an interface in Java. For example,

```
interface Language {

  public void getType();



  public void getVersion();

}
```

Here,

- `Language` is an interface.
- It includes abstract methods: `getType()` and `getVersion()`.

Implementing an Interface

Like abstract classes, we cannot create objects of interfaces.

To use an interface, other classes must implement it. We use the `implements` keyword to implement an interface.

Example 1: Java Interface

```java
interface Polygon {

  void getArea(int length, int breadth);

}



// implement the Polygon interface

class Rectangle implements Polygon {



  // implementation of abstract method

  public void getArea(int length, int breadth) {

    System.out.println("The area of the rectangle is " + (length * breadth));

  }

}



class Main {

  public static void main(String[] args) {
    Rectangle r1 = new Rectangle();

    r1.getArea(5, 6);

  }

}
```

Output

```
The area of the rectangle is 30
```

In the above example, we have created an interface named `Polygon`. The interface contains an abstract method `getArea()`.

Here, the `Rectangle` class implements `Polygon`. And, provides the implementation of the `getArea()` method.

Example 2: Java Interface

```
// create an interface

interface Language {

  void getName(String name);

}



// class implements interface

class ProgrammingLanguage implements Language {



  // implementation of abstract method

  public void getName(String name) {

    System.out.println("Programming Language: " + name);

  }
}


class Main {
  public static void main(String[] args) {
    ProgrammingLanguage language = new ProgrammingLanguage();
    language.getName("Java");
  }
}
```

Output

```
Programming Language: Java
```

In the above example, we have created an interface named `Language`. The interface includes an abstract method `getName()`.

Here, the `ProgrammingLanguage` class implements the interface and provides the implementation for the method.

Implementing Multiple Interfaces

In Java, a class can also implement multiple interfaces. For example,

```
interface A {
  // members of A
}


interface B {
  // members of B
}
```

```
class C implements A, B {

   // abstract members of A

   // abstract members of B

}
```

Extending an Interface

Similar to classes, interfaces can extend other interfaces. The `extends` keyword is used for extending interfaces. For example,

```
interface Line {

   // members of Line interface

}



// extending interface

interface Polygon extends Line {

   // members of Polygon interface

   // members of Line interface

}
```

Here, the `Polygon` interface extends the `Line` interface. Now, if any class implements `Polygon`, it should provide implementations for all the abstract methods of both `Line` and `Polygon`.

Extending Multiple Interfaces

An interface can extend multiple interfaces. For example,

```
interface A {

   ...
}

interface B {

    ...

}



interface C extends A, B {

    ...

}
```

Advantages of Interface in Java

Now that we know what interfaces are, let's learn about why interfaces are used in Java.

- Similar to abstract classes, interfaces help us to achieve abstraction in Java.

  Here, we know `getArea()` calculates the area of polygons but the way area is calculated is different for different polygons. Hence, the implementation of `getArea()` is independent of one another.
- Interfaces provide specifications that a class (which implements it) must follow.

  In our previous example, we have used `getArea()` as a specification inside the interface `Polygon`. This is like setting a rule that we should be able to get the area of every polygon.

  Now any class that implements the `Polygon` interface must provide an implementation for the `getArea()` method.

Interfaces are also used to achieve multiple inheritance in Java. For example,

```
interface Line {

...
```

```
}

interface Polygon {
...
}

class Rectangle implements Line, Polygon {
...
```

-
  ```
  }
  ```

  Here, the class `Rectangle` is implementing two different interfaces. This is how we achieve multiple inheritance in Java.

Note: All the methods inside an interface are implicitly `public` and all fields are implicitly `public static final`. For example,

```
interface Language {

  // by default public static final
  String type = "programming language";

  // by default public
  void getName();
}
```

---

default methods in Java Interfaces

With the release of Java 8, we can now add methods with implementation inside an interface. These methods are called default methods.

To declare default methods inside interfaces, we use the `default` keyword. For example,

```
public default void getSides() {

    // body of getSides()

}
```

Why default methods?

Let's take a scenario to understand why default methods are introduced in Java.

Suppose, we need to add a new method in an interface.

We can add the method in our interface easily without implementation. However, that's not the end of the story. All our classes that implement that interface must provide an implementation for the method.

If a large number of classes were implementing this interface, we need to track all these classes and make changes to them. This is not only tedious but error-prone as well.

To resolve this, Java introduced default methods. Default methods are inherited like ordinary methods.

Let's take an example to have a better understanding of default methods.

Example: Default Method in Java Interface

```
interface Polygon {

  void getArea();



  // default method

  default void getSides() {

    System.out.println("I can get sides of a polygon.");
    }

}


// implements the interface

class Rectangle implements Polygon {

  public void getArea() {

      int length = 6;

      int breadth = 5;

      int area = length * breadth;

      System.out.println("The area of the rectangle is " + area);

    }


  // overrides the getSides()

  public void getSides() {

      System.out.println("I have 4 sides.");

    }

}


// implements the interface

class Square implements Polygon {

  public void getArea() {

      int length = 5;

      int area = length * length;
```

```
        System.out.println("The area of the square is " + area);

    }

}



class Main {

    public static void main(String[] args) {



        // create an object of Rectangle

        Rectangle r1 = new Rectangle();

        r1.getArea();

        r1.getSides();



        // create an object of Square

        Square s1 = new Square();

        s1.getArea();

        s1.getSides();

    }

}
```

Output

```
The area of the rectangle is 30

I have 4 sides.

The area of the square is 25

I can get sides of a polygon.
```

In the above example, we have created an interface named `Polygon`. It has a default method `getSides()` and an abstract method `getArea()`.

Here, we have created two classes `Rectangle` and `Square` that implement `Polygon`.

The `Rectangle` class provides the implementation of the `getArea()` method and overrides the `getSides()` method. However, the `Square` class only provides the implementation of the `getArea()` method.

Now, while calling the `getSides()` method using the `Rectangle` object, the overridden method is called. However, in the case of the `Square` object, the default method is called.

---

private and static Methods in Interface

The Java 8 also added another feature to include static methods inside an interface.

Similar to a class, we can access static methods of an interface using its references. For example,

```
// create an interface
interface Polygon {
  staticMethod(){..}
}

// access static method
Polygon.staticMethod();
```

Note: With the release of Java 9, private methods are also supported in interfaces.

We cannot create objects of an interface. Hence, private methods are used as helper methods that provide support to other methods in interfaces.

Practical Example of Interface

Let's see a more practical example of Java Interface.

```
// To use the sqrt function

import java.lang.Math;



interface  Polygon {

   void getArea();



 // calculate the perimeter of a Polygon

   default void getPerimeter(int... sides) {

      int perimeter = 0;

      for (int side: sides) {

         perimeter += side;

      }



   System.out.println("Perimeter: " + perimeter);

   }

}



class Triangle implements Polygon {

   private int a, b, c;

   private double s, area;



// initializing sides of a triangle

   Triangle(int a, int b, int c) {
        this.a = a;

        this.b = b;

        this.c = c;

        s = 0;

    }



// calculate the area of a triangle

    public void getArea() {

        s = (double) (a + b + c)/2;

        area = Math.sqrt(s*(s-a)*(s-b)*(s-c));

        System.out.println("Area: " + area);

    }

}



class Main {

    public static void main(String[] args) {

        Triangle t1 = new Triangle(2, 3, 4);



// calls the method of the Triangle class

        t1.getArea();



// calls the method of Polygon

        t1.getPerimeter(2, 3, 4);
    }
}
```

Output

```
Area: 2.9047375096555625
Perimeter: 9
```

In the above program, we have created an interface named `Polygon`. It includes a default method `getPerimeter()` and an abstract method `getArea()`.

We can calculate the perimeter of all polygons in the same manner so we implemented the body of `getPerimeter()` in `Polygon`.

Now, all polygons that implement `Polygon` can use `getPerimeter()` to calculate perimeter.

However, the rule for calculating the area is different for different polygons. Hence, `getArea()` is included without implementation.

Any class that implements `Polygon` must provide an implementation of `getArea()`.

6) Java Polymorphism

we will learn about Java polymorphism and its implementation with the help of examples.

Polymorphism is an important concept of object-oriented programming. It simply means more than one form.

That is, the same entity (method or operator or object) can perform different operations in different scenarios.

Example: Java Polymorphism

```
class Polygon {
  // method to render a shape

  public void render() {

    System.out.println("Rendering Polygon...");

  }

}



class Square extends Polygon {



  // renders Square

  public void render() {

    System.out.println("Rendering Square...");

  }

}



class Circle extends Polygon {



  // renders circle

  public void render() {

    System.out.println("Rendering Circle...");

  }

}



class Main {
```

```
public static void main(String[] args) {


    // create an object of Square

    Square s1 = new Square();

    s1.render();


    // create an object of Circle

    Circle c1 = new Circle();

    c1.render();

  }

}
```

Output

```
Rendering Square...

Rendering Circle...
```

In the above example, we have created a superclass: `Polygon` and two subclasses: `Square` and `Circle`. Notice the use of the `render()` method.

The main purpose of the `render()` method is to render the shape. However, the process of rendering a square is different than the process of rendering a circle.

Hence, the `render()` method behaves differently in different classes. Or, we can say `render()` is polymorphic.

Why Polymorphism?

Polymorphism allows us to create consistent code. In the previous example, we can also create different methods: `renderSquare()` and `renderCircle()` to render `Square` and `Circle`, respectively.

This will work perfectly. However, for every shape, we need to create different methods. It will make our code inconsistent.

To solve this, polymorphism in Java allows us to create a single method `render()` that will behave differently for different shapes.

Note: The `print()` method is also an example of polymorphism. It is used to print values of different types like `char`, `int`, `string`, etc.

We can achieve polymorphism in Java using the following ways:

1. Method Overriding
2. Method Overloading
3. Operator Overloading

Java Method Overriding

During inheritance in Java, if the same method is present in both the superclass and the subclass. Then, the method in the subclass overrides the same method in the superclass. This is called method overriding.

In this case, the same method will perform one operation in the superclass and another operation in the subclass. For example,

Example 1: Polymorphism using method overriding

```
class Language {

  public void displayInfo() {

    System.out.println("Common English Language");

  }

}
```

```
class Java extends Language {

  @Override

  public void displayInfo() {

    System.out.println("Java Programming Language");

  }

}



class Main {

  public static void main(String[] args) {



    // create an object of Java class

    Java j1 = new Java();

    j1.displayInfo();



    // create an object of Language class

    Language l1 = new Language();

    l1.displayInfo();

  }

}
```

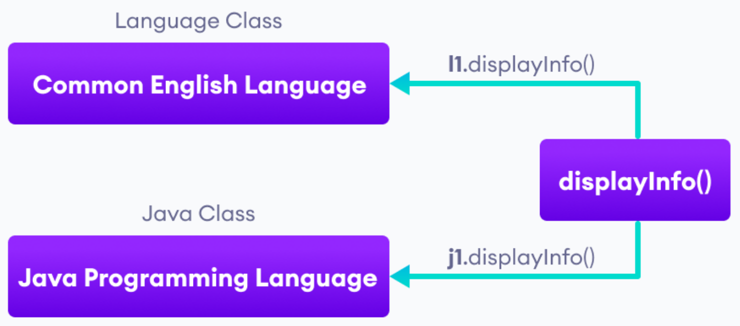
Output:

```
Java Programming Language

Common English Language
```

In the above example, we have created a superclass named `Language` and a subclass named `Java`. Here, the method `displayInfo()` is present in both `Language` and `Java`.

The use of `displayInfo()` is to print the information. However, it is printing different information in `Language` and `Java`.

Based on the object used to call the method, the corresponding information is printed.



Working of Java Polymorphism

> Note: The method that is called is determined during the execution of the program. Hence, method overriding is a run-time polymorphism.

---

2. Java Method Overloading

In a Java class, we can create methods with the same name if they differ in parameters. For example,

```
void func() { ... }
```

```
void func(int a) { ... }
```

```
float func(double a) { ... }
```

```
float func(int a, float b) { ... }
```

This is known as method overloading in Java. Here, the same method will perform different operations based on the parameter.

Example 3: Polymorphism using method overloading

```
class Pattern {
  // method without parameter

  public void display() {

    for (int i = 0; i < 10; i++) {

      System.out.print("*");

    }

  }



  // method with single parameter

  public void display(char symbol) {

    for (int i = 0; i < 10; i++) {

      System.out.print(symbol);

    }

  }

}



class Main {

  public static void main(String[] args) {

    Pattern d1 = new Pattern();



    // call method without any argument

    d1.display();

    System.out.println("\n");
    // call method with a single argument
    d1.display('#');
  }
}
```

Output:

```
**********



##########
```

In the above example, we have created a class named `Pattern`. The class contains a method named `display()` that is overloaded.

```
// method with no arguments
display() {...}



// method with a single char type argument
display(char symbol) {...}
```

Here, the main function of `display()` is to print the pattern. However, based on the arguments passed, the method is performing different operations:

- prints a pattern of `*`, if no argument is passed or
- prints pattern of the parameter, if a single `char` type argument is passed.

Note: The method that is called is determined by the compiler. Hence, it is also known as compile-time polymorphism.

---

3. Java Operator Overloading

Some operators in Java behave differently with different operands. For example,

- `+` operator is overloaded to perform numeric addition as well as string concatenation, and
- operators like `&`, `|`, and `!` are overloaded for logical and bitwise operations.

Let's see how we can achieve polymorphism using operator overloading.

The `+` operator is used to add two entities. However, in Java, the `+` operator performs two operations.

1. When `+` is used with numbers (integers and floating-point numbers), it performs mathematical addition. For example,

```
int a = 5;

int b = 6;



// + with numbers

int sum = a + b;  // Output = 11
```

2. When we use the `+` operator with strings, it will perform string concatenation (join two strings). For example,

```
String first = "Java ";

String second = "Programming";



// + with strings

name = first + second;  // Output = Java Programming
```

Here, we can see that the `+` operator is overloaded in Java to perform two operations: addition and concatenation.

Note: In languages like C++, we can define operators to work differently for different operands. However, Java doesn't support user-defined operator overloading.

Polymorphic Variables

A variable is called polymorphic if it refers to different values under different conditions.

Object variables (instance variables) represent the behavior of polymorphic variables in Java. It is because object variables of a class can refer to objects of its class as well as objects of its subclasses.

Example: Polymorphic Variables

```
class ProgrammingLanguage {

  public void display() {

    System.out.println("I am Programming Language.");

  }

}



class Java extends ProgrammingLanguage {

  @Override

  public void display() {

    System.out.println("I am Object-Oriented Programming Language.");

  }

}



class Main {

  public static void main(String[] args) {
    // declare an object variable

    ProgrammingLanguage pl;



    // create object of ProgrammingLanguage

    pl = new ProgrammingLanguage();

    pl.display();

// create object of Java class

    pl = new Java();

    pl.display();

  }

}
```

Output:

```
I am Programming Language.

I am Object-Oriented Programming Language.
```

In the above example, we have created an object variable `pl` of the `ProgrammingLanguage` class. Here, `pl` is a polymorphic variable. This is because,

- In statement `pl = new ProgrammingLanguage()`, `pl` refer to the object of the `ProgrammingLanguage` class.
- And, in statement `pl = new Java()`, `pl` refer to the object of the `Java` class.

This is an example of upcasting in Java.

7) Java Encapsulation

you will learn about encapsulation and data hiding in Java with the help of examples.

Java Encapsulation

Encapsulation is one of the key features of object-oriented programming. Encapsulation refers to the bundling of fields and methods inside a single class.

It prevents outer classes from accessing and changing fields and methods of a class. This also helps to achieve data hiding.

Example 1: Java Encapsulation

```
class Area {



  // fields to calculate area

  int length;

  int breadth;



  // constructor to initialize values

  Area(int length, int breadth) {

    this.length = length;

    this.breadth = breadth;

  }



  // method to calculate area

  public void getArea() {

    int area = length * breadth;

    System.out.println("Area: " + area);
  }
}


class Main {
  public static void main(String[] args) {


    // create object of Area
    // pass value of length and breadth
    Area rectangle = new Area(5, 6);
    rectangle.getArea();
  }
}
```

Output

```
Area: 30
```

In the above example, we have created a class named `Area`. The main purpose of this class is to calculate the area.

To calculate an area, we need two variables: `length` and `breadth` and a method: `getArea()`. Hence, we bundled these fields and methods inside a single class.

Here, the fields and methods can be accessed from other classes as well. Hence, this is not data hiding.

This is only encapsulation. We are just keeping similar codes together.

Note: People often consider encapsulation as data hiding, but that's not entirely true.

Encapsulation refers to the bundling of related fields and methods together. This can be used to achieve data hiding. Encapsulation in itself is not data hiding.

Why Encapsulation?

- In Java, encapsulation helps us to keep related fields and methods together, which makes our code cleaner and easy to read.

It helps to control the values of our data fields. For example,

```
class Person {

  private int age;



  public void setAge(int age) {

    if (age >= 0) {

      this.age = age;

    }

  }
```

- `}`

  Here, we are making the `age` variable `private` and applying logic inside the `setAge()` method. Now, `age` cannot be negative.

The getter and setter methods provide read-only or write-only access to our class fields. For example,

```
getName()  // provides read-only access
```

- `setName() // provides write-only access`
- It helps to decouple components of a system. For example, we can encapsulate code into multiple bundles.

  These decoupled components (bundle) can be developed, tested, and debugged independently and concurrently. And, any changes in a particular component do not have any effect on other components.

- We can also achieve data hiding using encapsulation. In the above example, if we change the length and breadth variable into private, then the access to these fields is restricted.

  And, they are kept hidden from outer classes. This is called data hiding.

Data Hiding

Data hiding is a way of restricting the access of our data members by hiding the implementation details. Encapsulation also provides a way for data hiding.

We can use access modifiers to achieve data hiding. For example,

Example 2: Data hiding using the private specifier

```
class Person {

  // private field
  private int age;

  // getter method
  public int getAge() {
    return age;
  }

  // setter method
  public void setAge(int age) {
    this.age = age;
    }

}



class Main {

    public static void main(String[] args) {



        // create an object of Person

        Person p1 = new Person();



        // change age using setter

        p1.setAge(24);



        // access age using getter

        System.out.println("My age is " + p1.getAge());

    }

}
```

Output

```
My age is 24
```

In the above example, we have a `private` field `age`. Since it is `private`, it cannot be accessed from outside the class.

In order to access `age`, we have used `public` methods: `getAge()` and `setAge()`. These methods are called getter and setter methods.

Making `age` private allowed us to restrict unauthorized access from outside the class. This is data hiding.

If we try to access the `age` field from the `Main` class, we will get an error.

```
// error: age has private access in Person

p1.age = 24;
```

SEARCHING Algorithms

1) Linear Search

Linear or Sequential Search is the simplest of search algorithms. While it most certainly is the simplest, it's most definitely not the most common, due to its inefficiency. It's a brute-force algorithm. Very rarely is it used in production, and in most cases, it's outperformed by other algorithms.

Linear Search has no pre-requisites for the state of the underlying data structure.

Explanation

Linear Search involves sequential searching for an element in the given data structure until either the element is found or the end of the structure is reached.

If the element is found, we usually just return its position in the data structure. If not, we usually return `-1`.

Implementation

Now let's see how to implement Linear Search in Java:

```
public static int linearSearch(int arr[], int elementToSearch) {



    for (int index = 0; index < arr.length; index++) {

        if (arr[index] == elementToSearch)

            return index;

    }

    return -1;

}
```

To test it, we'll use a simple Array of integers:

```
int index = linearSearch(new int[]{89, 57, 91, 47, 95, 3, 27, 22, 67, 99},
67);

print(67, index);
```

With a simple helper method to print the result:

```
public static void print(int elementToSearch, int index) {

    if (index == -1){

        System.out.println(elementToSearch + " not found.");

    }

    else {

        System.out.println(elementToSearch + " found at index: " + index);

    }
}
```

Output:

```
67 found at index: 8
```

Time Complexity

Here we are iterating through the entire set of `N` elements sequentially to get the location of the element being searched. The worst case for this algorithm will be if the element we are searching for is the last element in the array.

In this case, we will iterate `N` times before we find the element.

Hence, the Time Complexity of Linear search is *O(N)*.

Space Complexity

This type of search requires only a single unit of memory to store the element being searched. This is not relevant to the size of the input Array.

Hence, the Space Complexity of Linear Search is *O(1)*.

Applications

Linear Search can be used for searching in a small and unsorted set of data which is guaranteed not to increase in size by much.

It is a very basic search algorithm but due to its linear increase in time complexity, it does not find application in many production systems.

2) Binary Search

Binary or Logarithmic Search is one of the most commonly used search algorithms primarily due to its quick search time.

Explanation

This kind of search uses the Divide and Conquer methodology and requires the data set to be sorted beforehand.

It divides the input collection into equal halves, and with each iteration compares the goal element with the element in the middle.

If the element is found, the search ends. Else, we continue looking for the element by dividing and selecting the appropriate partition of the array, based on if the goal element is smaller or bigger than the middle element.

This is why it's important to have a sorted collection for Binary Search.

The search terminates when the `firstIndex` (our pointer) goes past `lastIndex` (last element), which implies we have searched the whole array and the element is not present.

There are two ways to implement this algorithm - iterative and recursive.

There *shouldn't* be a difference regarding time and space complexity between these two implementations, though this doesn't hold true to all languages.

Implementation

Iterative

Let's first take a look at the iterative approach:

```
public static int binarySearch(int arr[], int elementToSearch) {



    int firstIndex = 0;

    int lastIndex = arr.length - 1;



    // termination condition (element isn't present)

    while(firstIndex <= lastIndex) {

        int middleIndex = (firstIndex + lastIndex) / 2;

        // if the middle element is our goal element, return its index
        if (arr[middleIndex] == elementToSearch) {

            return middleIndex;

        }



        // if the middle element is smaller

        // point our index to the middle+1, taking the first half out of
consideration

        else if (arr[middleIndex] < elementToSearch)

            firstIndex = middleIndex + 1;



        // if the middle element is bigger

        // point our index to the middle-1, taking the second half out of
consideration

        else if (arr[middleIndex] > elementToSearch)

            lastIndex = middleIndex - 1;



    }

    return -1;

}
```

We can use the algorithm like this:

```
int index = binarySearch(new int[]{89, 57, 91, 47, 95, 3, 27, 22, 67, 99},
67);

print(67, index);
```

Output:

```
67 found at index: 5
```

Recursive

And now let's take a look at the recursive implementation:

```
public static int recursiveBinarySearch(int arr[], int firstElement, int
lastElement, int elementToSearch) {


    // termination condition

    if (lastElement >= firstElement) {

        int mid = firstElement + (lastElement - firstElement) / 2;


        // if the middle element is our goal element, return its index

        if (arr[mid] == elementToSearch)

            return mid;


        // if the middle element is bigger than the goal element

        // recursively call the method with narrowed data

        if (arr[mid] > elementToSearch)

            return recursiveBinarySearch(arr, firstElement, mid - 1,
elementToSearch);


        // else, recursively call the method with narrowed data
        return recursiveBinarySearch(arr, mid + 1, lastElement,
elementToSearch);

    }



    return -1;

}
```

The difference in the recursive approach is that we invoke the method itself once we get the new partition. In the iterative approach, whenever we determined the new partition we modified the first and last elements and repeated the process in the same loop.

Another difference here is that recursive calls are pushed on the method call-stack and they occupy one unit of space per recursive call.

We can use this algorithm like this:

```
int index = binarySearch(new int[]{3, 22, 27, 47, 57, 67, 89, 91, 95, 99}, 0,
10, 67);

print(67, index);
```

Output:

```
67 found at index: 5
```

Time Complexity

Since Binary Search divides the array into half each time its time complexity is *O(log(N))*. This time complexity is a marked improvement on the *O(N)* time complexity of Linear Search.

Space Complexity

This search requires only one unit of space to store the element to be searched. Hence, its space complexity is *O(1)*.

If Binary Search is implemented recursively, it needs to store the call to the method on a stack. This may require *O(log(N))* space in the worst case scenario.

Applications

It is the most commonly used search algorithm in most of the libraries for searching. The Binary Search tree is used by many data structures as well which store sorted data.

Binary Search is also implemented in Java APIs in the `Arrays.binarySearch` method.

QuickSort Algorithm

Quicksort is a sorting algorithm, which is leveraging the divide-and-conquer principle. It has an average *O(n log n)* complexity and it's one of the most used sorting algorithms, especially for big data volumes.

It's important to remember that Quicksort isn't a stable algorithm. A stable sorting algorithm is an algorithm where the elements with the same values appear in the same order in the sorted output as they appear in the input list.

The input list is divided into two sub-lists by an element called pivot; one sub-list with elements less than the pivot and another one with elements greater than the pivot. This process repeats for each sub-list.

2.1. Algorithm Steps

1. We choose an element from the list, called the pivot. We'll use it to divide the list into two sub-lists.
2. We reorder all the elements around the pivot – the ones with smaller value are placed before it, and all the elements greater than the pivot after it. After this step, the pivot is in its final position. This is the important partition step.
3. We apply the above steps recursively to both sub-lists on the left and right of the pivot.

As we can see, quicksort is naturally a recursive algorithm, like every divide and conquer approach.

Let's take a simple example in order to better understand this algorithm.

```
Arr[] = {5, 9, 4, 6, 5, 3}
```

1. Let's suppose we pick 5 as the pivot for simplicity
2. We'll first put all elements less than 5 in the first position of the array: {3, 4, 5, 6, 5, 9}
3. We'll then repeat it for the left sub-array {3,4}, taking 3 as the pivot
4. There are no elements less than 3
5. We apply quicksort on the sub-array in the right of the pivot, i.e. {4}
6. This sub-array consists of only one sorted element
7. We continue with the right part of the original array, {6, 5, 9} until we get the final ordered array

2.2. Choosing the Optimal Pivot

The crucial point in QuickSort is to choose the best pivot. The middle element is, of course, the best, as it would divide the list into two equal sub-lists.

But finding the middle element from an unordered list is difficult and time-consuming, that is why we take as pivot the first element, the last element, the median or any other random element.

3. Implementation in Java

The first method is *quickSort()* which takes as parameters the array to be sorted, the first and the last index. First, we check the indices and continue only if there are still elements to be sorted.

We get the index of the sorted pivot and use it to recursively call *partition()* method with the same parameters as the *quickSort()* method, but with different indices:

```
public void quickSort(int arr[], int begin, int end) {

    if (begin < end) {

        int partitionIndex = partition(arr, begin, end);



        quickSort(arr, begin, partitionIndex-1);

        quickSort(arr, partitionIndex+1, end);

    }

}
```

Let's continue with the *partition()* method. For simplicity, this function takes the last element as the pivot. Then, checks each element and swaps it before the pivot if its value is smaller.

By the end of the partitioning, all elements less then the pivot are on the left of it and all elements greater then the pivot are on the right of it. The pivot is at its final sorted position and the function returns this position:

```
private int partition(int arr[], int begin, int end) {

    int pivot = arr[end];

    int i = (begin-1);



    for (int j = begin; j < end; j++) {

        if (arr[j] <= pivot) {

            i++;



            int swapTemp = arr[i];

            arr[i] = arr[j];

            arr[j] = swapTemp;

        }

    }



    int swapTemp = arr[i+1];

    arr[i+1] = arr[end];

    arr[end] = swapTemp;



    return i+1;

}
```

4. Algorithm Analysis

4.1. Time Complexity

In the best case, the algorithm will divide the list into two equal size sub-lists. So, the first iteration of the full *n*-sized list needs *O(n)*. Sorting the remaining two sub-lists with *n/2* elements takes *2*O(n/2)* each. As a result, the QuickSort algorithm has the complexity of *O(n log n)*.

In the worst case, the algorithm will select only one element in each iteration, so *O(n) + O(n-1) + … + O(1)*, which is equal to *O(n2)*.

On the average QuickSort has *O(n log n)* complexity, making it suitable for big data volumes.

4.2. QuickSort vs MergeSort

Let's discuss in which cases we should choose QuickSort over MergeSort.

Although both Quicksort and Mergesort have an average time complexity of *O(n log n)*, Quicksort is the preferred algorithm, as it has an *O(log(n))* space complexity. Mergesort, on the other hand, requires *O(n)* extra storage, which makes it quite expensive for arrays.

Quicksort requires to access different indices for its operations, but this access is not directly possible in linked lists, as there are no continuous blocks; therefore to access an element we have to iterate through each node from the beginning of the linked list. Also, Mergesort is implemented without extra space for *LinkedLists.*

In such case, overhead increases for Quicksort and Mergesort is generally preferred.

5. Conclusion

Quicksort is an elegant sorting algorithm that is very useful in most cases.

It's generally an "in-place" algorithm, with the average time complexity of *O(n log n).*

Another interesting point to mention is that Java's *Arrays.sort()* method uses Quicksort for sorting arrays of primitives. The implementation uses two pivots and performs much better than our simple solution, that is why for production code it's usually better to use library methods.

Revision

Bubble Sort

The two algorithms that most beginners start their sorting career with would be bubble sort and selection sort. These sorting algorithms are not very efficient, but they provide a key insight into what sorting is and how a sorting algorithm works behind the scenes. Bubble sort relies on multiple swaps instead of a single like selection sort. The algorithm continues to go through the array repeatedly, swapping elements that are not in their correct location.

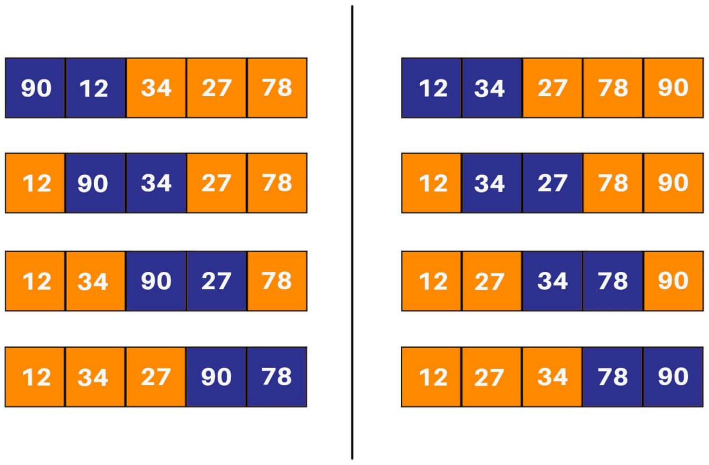
Algorithm:

1. START
2. Run two loops – an inner loop and an outer loop.
3. Repeat steps till the outer loop are exhausted.
4. If the current element in the inner loop is smaller than its next element, swap the values of the two elements.
5. END

Bubble Sort Java Code:

```java
class Sort

{

    static void bubbleSort(int arr[], int n)

    {

        if (n == 1)                         //passes are done

        {

            return;

        }



        for (int i=0; i<n-1; i++)       //iteration through unsorted
elements

        {

            if (arr[i] > arr[i+1])      //check if the elements are in order
            {                             //if not, swap them

                int temp = arr[i];

                arr[i] = arr[i+1];

                arr[i+1] = temp;

            }

        }



        bubbleSort(arr, n-1);            //one pass done, proceed to the next

    }



    void display(int arr[])                  //display the array

    {

        for (int i=0; i<arr.length; ++i)

        {

            System.out.print(arr[i]+" ");

        }

    }



    public static void main(String[] args)

    {

        Sort ob = new Sort();

        int arr[] = {6, 4, 5, 12, 2, 11, 9};

        bubbleSort(arr, arr.length);
        ob.display(arr);

    }

}
```

Explanation of how it works:



REVISE kaar heee

Insertion Sort

If you're quite done with more complex sorting algorithms and want to move on to something simpler: insertion sort is the way to go. While it isn't a much-optimized algorithm for sorting an array, it is one of the more easily understood ones. Implementation is pretty easy too. In insertion sort, one picks up an element and considers it to be the key. If the key is smaller than its predecessor, it is shifted to its correct location in the array.

Algorithm:

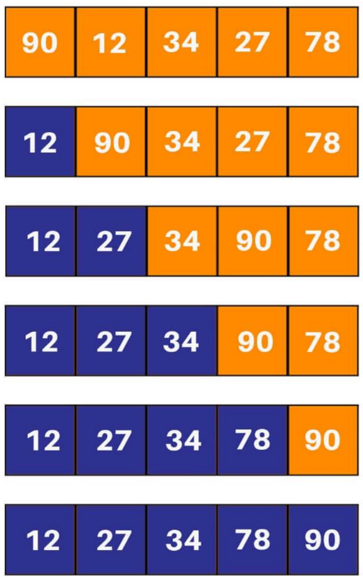
1. START
2. Repeat steps 2 to 4 till the array end is reached.
3. Compare the element at current index i with its predecessor. If it is smaller, repeat step 3.
4. Keep shifting elements from the "sorted" section of the array till the correct location of the key is found.

5. Increment loop variable.
6. END

Insertion Sort Java Code:

```
class Sort

{

    static void insertionSort(int arr[], int n)

    {

        if (n <= 1)                             //passes are done

        {

            return;

        }



        insertionSort( arr, n-1 );        //one element sorted, sort the
remaining array



        int last = arr[n-1];                         //last element of the
array

        int j = n-2;                                 //correct index of last
element of the array



        while (j >= 0 && arr[j] > last)                  //find the correct
index of the last element

        {
            arr[j+1] = arr[j];                          //shift section of
sorted elements upwards by one element if correct index isn't found

            j--;

        }

        arr[j+1] = last;                            //set the last element at
its correct index

    }



    void display(int arr[])                     //display the array

    {

        for (int i=0; i<arr.length; ++i)

        {

            System.out.print(arr[i]+" ");

        }

    }




    public static void main(String[] args)

    {

        int arr[] = {22, 21, 11, 15, 16};



        insertionSort(arr, arr.length);

        Sort ob = new Sort();

        ob.display(arr);
    }

}
```

Explanation of how it works:



Selection Sort

Quadratic sorting algorithms are some of the more popular sorting algorithms that are easy to understand and implement. These don't offer a unique or optimized approach for sorting the array - rather they should offer building blocks for the concept of sorting itself for someone new to it. In selection sort, two loops are used. The inner loop one picks the minimum element from the array and shifts it to its correct index indicated by the outer loop. In every run of the outer loop, one element is shifted to its correct location in the array. It is a very popular sorting algorithm in python as well.

Algorithm:

1. START
2. Run two loops: an inner loop and an outer loop.
3. Repeat steps till the minimum element are found.
4. Mark the element marked by the outer loop variable as a minimum.
5. If the current element in the inner loop is smaller than the marked minimum element, change the value of the minimum element to the current element.

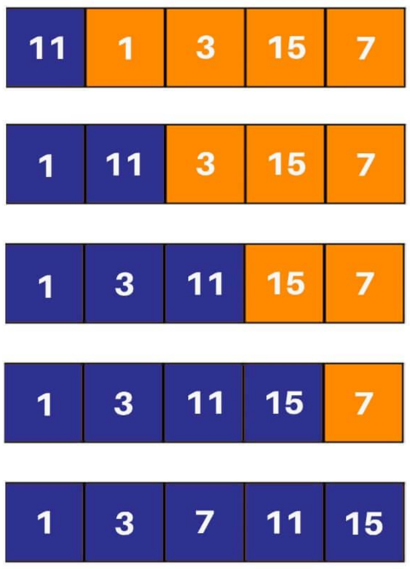
6. Swap the value of the minimum element with the element marked by the outer loop variable.
7. END

Selection Sort Java Code:

```
class Sort

{

    void selectionSort(int arr[])

    {

        int pos;

        int temp;

        for (int i = 0; i < arr.length; i++)

        {

            pos = i;

            for (int j = i+1; j < arr.length; j++)

           {

                if (arr[j] < arr[pos])                  //find the index of
the minimum element

                {

                    pos = j;

                }

            }



            temp = arr[pos];            //swap the current element with the
minimum element
```

```
            arr[pos] = arr[i];

            arr[i] = temp;

        }

    }



    void display(int arr[])                      //display the array

    {

        for (int i=0; i<arr.length; i++)

        {

            System.out.print(arr[i]+" ");

        }

    }



    public static void main(String args[])

    {

        Sort ob = new Sort();

        int arr[] = {64,25,12,22,11};

        ob.selectionSort(arr);

        ob.display(arr);

    }

}
```

Explanation of how it works:



Merge Sort

Merge sort is one of the most flexible sorting algorithms in java known to mankind (yes, no kidding). It uses the divide and conquers strategy for sorting elements in an array. It is also a stable sort, meaning that it will not change the order of the original elements in an array concerning each other. The underlying strategy breaks up the array into multiple smaller segments till segments of only two elements (or one element) are obtained. Now, elements in these segments are sorted and the segments are merged to form larger segments. This process continues till the entire array is sorted.

This algorithm has two main parts:

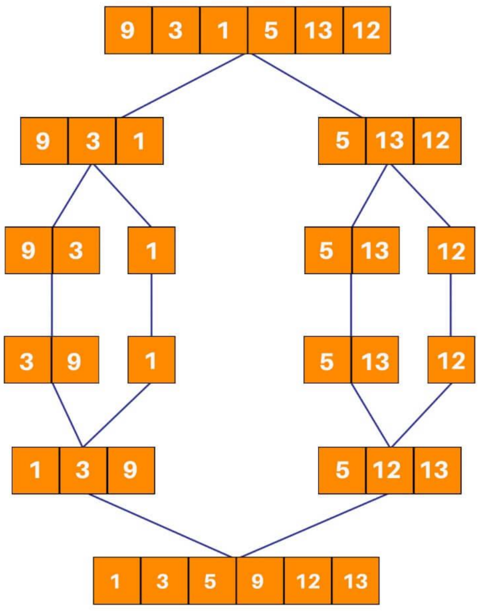
- mergeSort() – This function calculates the middle index for the subarray and then partitions the subarray into two halves. The first half runs from index left to middle, while the second half runs from index middle+1 to right. After the partitioning is done, this function automatically calls the merge() function for sorting the subarray being handled by the mergeSort() call.
- merge() – This function does the actual heavy lifting for the sorting process. It requires the input of four parameters – the array, the starting index (left), the middle index (middle), and the ending index (right). Once received, merge() will split the subarray into two subarrays – one left subarray and one right subarray. The left subarray runs from index left to middle,

while the right subarray runs from index middle+1 to right. This function then merges the two subarrays to get the sorted subarray.

Merge Sort Java Code:

```
class Sort

{

    void merge(int arr[], int left, int middle, int right)

    {

        int low = middle - left + 1;                    //size of the left
subarray

        int high = right - middle;                      //size of the right
subarray



        int L[] = new int[low];                             //create the
left and right subarray

        int R[] = new int[high];



        int i = 0, j = 0;



        for (i = 0; i < low; i++)                               //copy
elements into left subarray

        {

            L[i] = arr[left + i];

        }
        for (j = 0; j < high; j++)                              //copy
elements into right subarray

        {

            R[j] = arr[middle + 1 + j];

        }




        int k = left;                                           //get
starting index for sort

        i = 0;                                             //reset loop
variables before performing merge

        j = 0;


        while (i < low && j < high)                     //merge the left and
right subarrays

        {

            if (L[i] <= R[j])

            {

                arr[k] = L[i];

                i++;

            }

            else

            {

                arr[k] = R[j];
                j++;

            }

            k++;

        }



        while (i < low)                              //merge the remaining
elements from the left subarray

        {

            arr[k] = L[i];

            i++;

            k++;

        }



        while (j < high)                             //merge the remaining
elements from right subarray

        {

            arr[k] = R[j];

            j++;

            k++;

        }

    }
    void mergeSort(int arr[], int left, int right)       //helper function
that creates the sub cases for sorting

    {

        int middle;

        if (left < right) {                               //sort only if the
left index is lesser than the right index (meaning that sorting is done)

            middle = (left + right) / 2;



            mergeSort(arr, left, middle);                      //left subarray

            mergeSort(arr, middle + 1, right);                 //right subarray



            merge(arr, left, middle, right);                  //merge the two
subarrays

        }

    }



    void display(int arr[])                  //display the array

    {

        for (int i=0; i<arr.length; ++i)

        {

            System.out.print(arr[i]+" ");

        }

    }
    public static void main(String args[])

    {

        int arr[] = { 9, 3, 1, 5, 13, 12 };

        Sort ob = new Sort();

        ob.mergeSort(arr, 0, arr.length - 1);

        ob.display(arr);

    }

}
```

Explanation of how it works:



Heap Sort

Heap sort is one of the most important sorting methods in java that one needs to learn to get into sorting. It combines the concepts of a tree as well as sorting, properly reinforcing the use of concepts from both. A heap is a complete binary search tree where items are stored in a special order depending on the requirement. A min-heap contains the minimum element at the root, and every child of the root must be greater than the root itself. The children at the level after that must be greater than these children, and so on. Similarly, a max-heap contains the maximum element at the root. For the sorting process, the heap is stored as an array where for every parent node at the index i, the left child is at index 2 * i + 1, and the right child is at index 2 * i + 2.

A max heap is built with the elements of the unsorted array, and then the maximum element is extracted from the root of the array and then exchanged with the last element of the array. Once done, the max heap is rebuilt for getting the next maximum element. This process continues till there is only one node present in the heap.

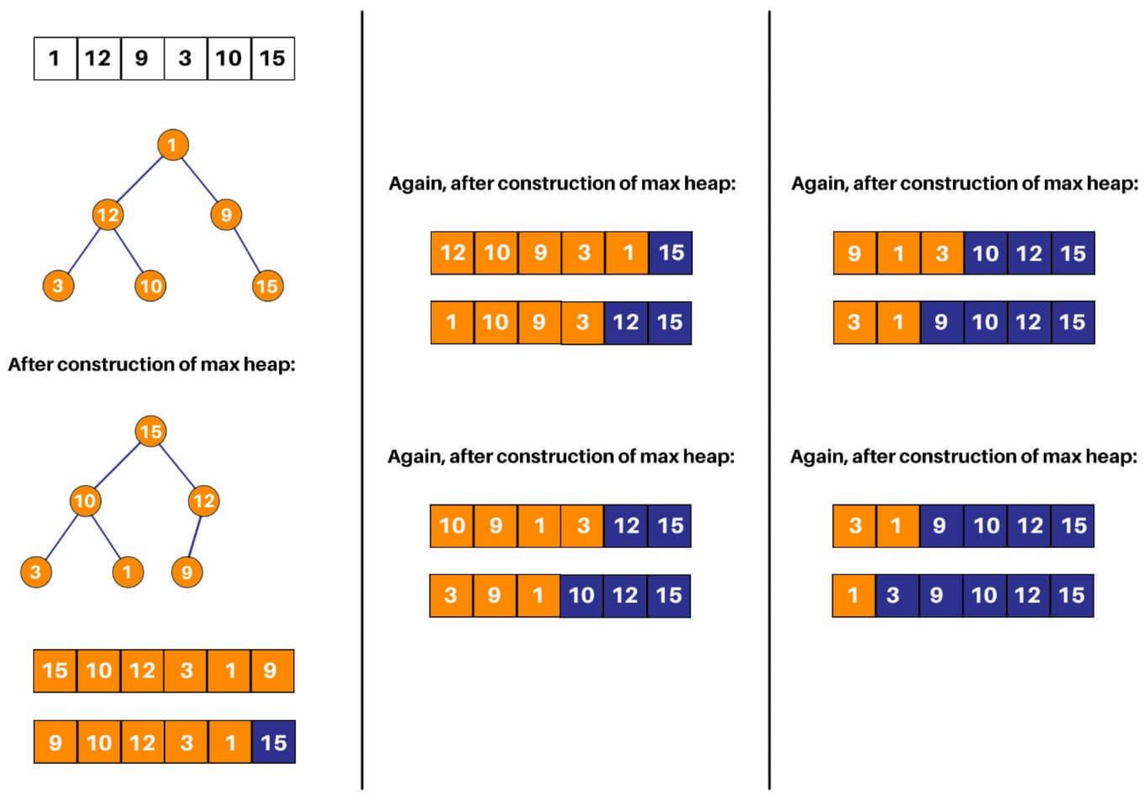
This algorithm has two main parts:-

- heapSort() – This function helps construct the max heap initially for use. Once done, every root element is extracted and sent to the end of the array. Once done, the max heap is reconstructed from the root. The root is again extracted and sent to the end of the array, and hence the process continues.
- heapify() – This function is the building block of the heap sort algorithm. This function determines the maximum from the element being examined as the root and its two children. If the maximum is among the children of the root, the root and its child are swapped. This process is then repeated for the new root. When the maximum element in the array is found (such that its children are smaller than it) the function stops. For the node at index i, the left child is at index 2 * i + 1, and the right child is at index 2 * i + 1. (indexing in an array starts from 0, so the root is at 0).

Heap Sort Java Code:

```
class Sort {

    public void heapSort(int arr[])

    {

        int temp;
        for (int i = arr.length / 2 - 1; i >= 0; i--)                //build
the heap

        {

            heapify(arr, arr.length, i);

        }



        for (int i = arr.length - 1; i > 0; i--)
//extract elements from the heap

        {

            temp = arr[0];
//move current root to end (since it is the largest)

            arr[0] = arr[i];

            arr[i] = temp;

            heapify(arr, i, 0);
//recall heapify to rebuild heap for the remaining elements

        }

    }



    void heapify(int arr[], int n, int i)

    {

        int MAX = i; // Initialize largest as root

        int left = 2 * i + 1; //index of the left child of ith node = 2*i + 1

        int right = 2 * i + 2; //index of the right child of ith node  = 2*i
+ 2

        int temp;
        if (left < n && arr[left] > arr[MAX])            //check if the left
child of the root is larger than the root

        {

            MAX = left;

        }



        if (right < n && arr[right] > arr[MAX])            //check if the
right child of the root is larger than the root

        {

            MAX = right;

        }



        if (MAX != i)

        {                                               //repeat the
procedure for finding the largest element in the heap

            temp = arr[i];

            arr[i] = arr[MAX];

            arr[MAX] = temp;

            heapify(arr, n, MAX);

        }

    }



    void display(int arr[])                 //display the array
    {

        for (int i=0; i<arr.length; ++i)

        {

            System.out.print(arr[i]+" ");

        }

    }



    public static void main(String args[])

    {

        int arr[] = { 1, 12, 9 , 3, 10, 15 };



        Sort ob = new Sort();

        ob.heapSort(arr);

        ob.display(arr);

    }

}
```

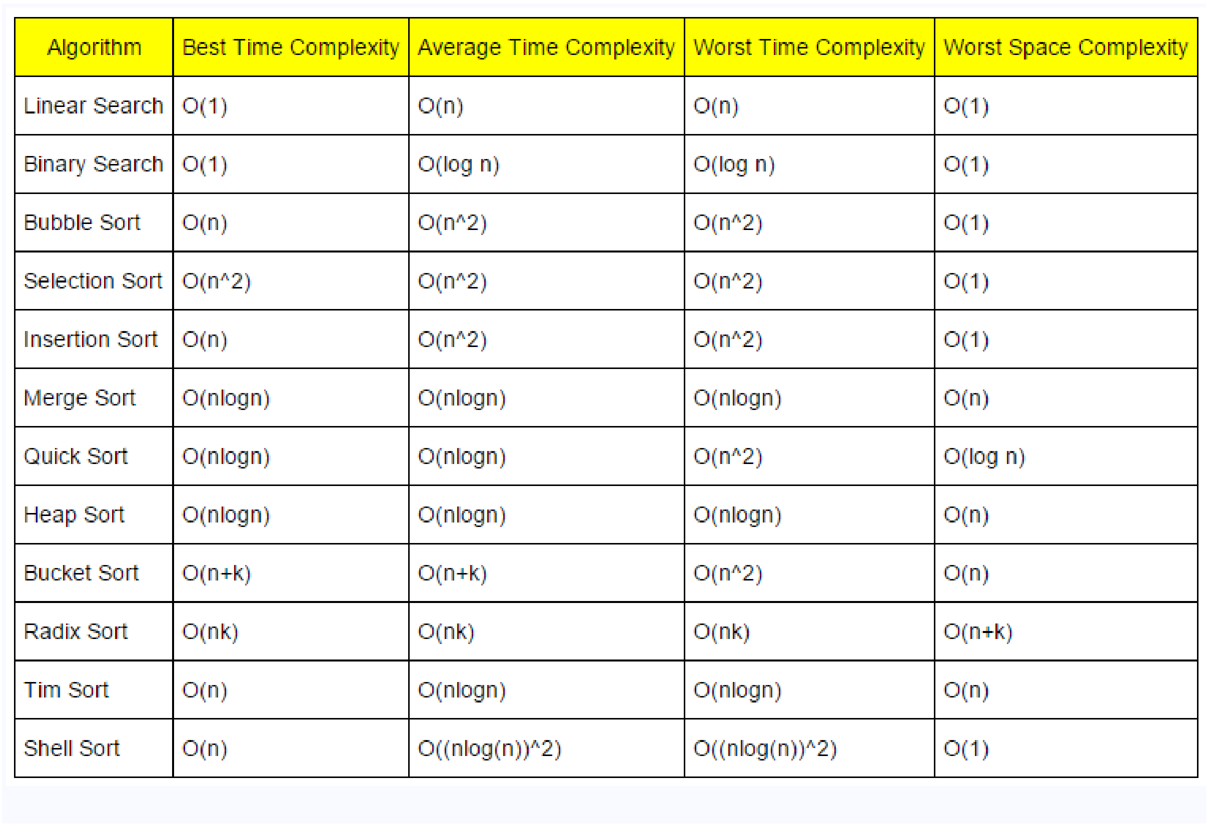
Explanation of how it works:


1 12 9 3 10 15
After construction of max heap:
15 10 12 3 1 9
9 10 12 3 1 15
Again, after construction of max heap:
12 10 9 3 1 15
1 10 9 3 12 15
Again, after construction of max heap:
10 9 1 3 12 15
3 9 1 10 12 15
Again, after construction of max heap:
9 1 3 10 12 15
3 1 9 10 12 15
Again, after construction of max heap:
3 1 9 10 12 15
1 3 9 10 12 15

Java Sorting Algorithms Cheat Sheet

Here is a cheat sheet for all sorting algorithms in Java:

Algorithm	Approach	Best Time Complexity
Merge Sort	Split the array into smaller subarrays till pairs of elements are achieved, and then combine them in such a way that they are in order.	O(n log (n))
Heap Sort	Build a max (or min) heap and extract the first element of the heap (or root), and then send it to the end of the heap. Decrement the size of the heap and repeat till the heap has only one node.	O(n log (n))
Insertion Sort	In every run, compare it with the predecessor. If the current element is not in the correct location, keep shifting the predecessor subarray till the correct index for the element is found.	O (n)
Selection Sort	Find the minimum element in each run of the array and swap it with the element at the current index is compared.	O(n^2)
Bubble Sort	Keep swapping elements that are not in their right location till the array is sorted.	O (n)



Algorithm	Best Time Complexity	Average Time Complexity	Worst Time Complexity	Worst Space Complexity
Linear Search	O(1)	O(n)	O(n)	O(1)
Binary Search	O(1)	O(log n)	O(log n)	O(1)
Bubble Sort	O(n)	O(n^2)	O(n^2)	O(1)
Selection Sort	O(n^2)	O(n^2)	O(n^2)	O(1)
Insertion Sort	O(n)	O(n^2)	O(n^2)	O(1)
Merge Sort	O(nlogn)	O(nlogn)	O(nlogn)	O(n)
Quick Sort	O(nlogn)	O(nlogn)	O(n^2)	O(log n)
Heap Sort	O(nlogn)	O(nlogn)	O(nlogn)	O(n)
Bucket Sort	O(n+k)	O(n+k)	O(n^2)	O(n)
Radix Sort	O(nk)	O(nk)	O(nk)	O(n+k)
Tim Sort	O(n)	O(nlogn)	O(nlogn)	O(n)
Shell Sort	O(n)	O((nlog(n))^2)	O((nlog(n))^2)	O(1)