Abstraction and Abstract Data Types

- **Abstraction**:
  - Whatever is visible to the user?

- Examples: Variable names & real numbers.
  - How real numbers are implemented?
  - How arrays are implemented?
    - The abstraction is rectangular arrays
    - The implementation is one-dimensional array.

- Given the following algorithm:

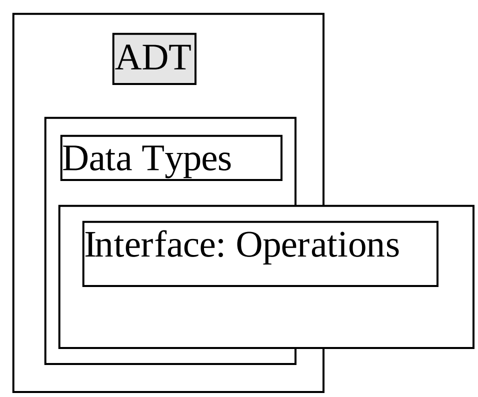
```
S = set of persons.
X in S;
smallest-age = X;
S = S-{X};
While S is not empty do
        Y in S;
        S = S-{Y};
        If age(Y) < age(X)
        Then smallest = Y;
Endwhile;
```

  - What do you need to implement such a problem?

- For a given implementation,
  - we need to make the following assumptions:
    1. The data we are dealing with are of some **data types**.
    2. A construct to store the data types: **Data Structures**
    3. The **set of operations** on the data types defined in(1).
- (1) & (3) =====> Abstract Data Types (**ADT**).
- (2) =====> A way to implement the ADT.

- Data Types: (1)
  - Definition: The data type of a variable determines the set of values the variable can take.
  - Simple data types:
    - Integer, real, character, enumeration types, etc.
  - Structured data types:
    - arrays, records, files, and sets.
- Data Structures: (2)
  - Definition:
    - A data structure (D. S.) is a construct that you can define within a programming language to store a collection of data types.
- Examples:
  - All structured data types are D.S.
  - Trees, Linked lists, etc.

- **Abstract Data Types (ADT):** (3)
    - Definition:
        - An abstract data type (ADT) is characterized by the following properties:
            - It exports a type, called domain.
            - It exports a set of operations. This set is called **<u>interface</u>**.
            - Operations of the interface are the one and only access mechanism to the type's data structure.
            - Axioms and preconditions define the application domain of the type.



            - The first property allows the creation of more than one instance of an ADT object.
            - The second property defines the only possible operations on the ADT object.
            - The third property prevents using other operations different from the ones defined in the interface.
            - Finally, the application domain is defined by the semantical meaning of provided operations. Axioms and preconditions include statements such as:
                - The denominator of a fraction is different from zero.
                - An empty list is a list.'

- **OOP and ADT:**
  - A class is an actual representation of an ADT.
  - It provides implementation details for the data structure used and operations.
  - OOP supports the implementation of an ADT using information hiding.
  - Information hiding
    - is used to hide the implementation details
    - Prevent users from directly accessing data members (**private** access modifier).

- **Example:**

    - ADT: Fraction
        - Data type:
            - numerator: integer;
            - denominator: integer;
        - Data structure: data types
        - Operations:
            - Add, multiply, equal, reduce, divide, etc.
        - Axioms and preconditions:
            - The denominator should be different from zero.

    - Java Implementation:

```
//Fraction ADT
public class Fraction {

     private int numerator;
     private int denominator;
     public Fraction(){
          numerator = 0;
          denominator = 1;
     }
     public Fraction(int num, int deno){
          numerator = num;
          denominator = deno;
            if (denominator == 0){
             throw new IllegalArgumentException("Denominator cannot be zero");
      }
     }
      public void reduceF(){
       int n = numerator;
       int d = denominator;

        while (d != 0) {
          int t = d;
          d = n % d;
          n = t;
       }
     numerator /= n;
     denominator /= n;
    }
```

```java
    public int getNumerator() {
        return this.numerator;
    }

    public int getDenominator() {
        return this.denominator;
    }
     public Fraction add(Fraction f1, Fraction f2){
        Fraction f = new Fraction();
        f.numerator = f1.numerator * f2.denominator + f1.denominator *
f2.numerator;
        f.denominator = f1.denominator * f2.denominator;
        f.reduceF();
        return(f);
    }
    public Fraction sub(Fraction f1, Fraction f2){
        //Implement this function.
    }
    public Fraction multiply(Fraction f1, Fraction f2){
        //Implement this function.
    }
    public Fraction divide (Fraction f1, Fraction f2){
        //Implement this function.
    }
    public boolean equals(Fraction f2){
        return getNumerator()*f2.getDenominator() ==
f2.getNumerator()*getDenominator();
    }
    public void printF(Fraction f){
         System.out.println (f.numerator +  "/" +  f.denominator) ;
     }
}
```

- **Programming Assignment:**
  - Design and implement the missing operations in the Fraction ADT:
    - Subtraction:

$$\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}$$

    - Multiplication:

$$\frac{a}{b} * \frac{c}{d} = \frac{ac}{bd}$$

    - Division

$$\frac{a}{b} \div \frac{c}{d} = \frac{ad}{bc}$$

  - Test your implementation.