NUS
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School of Computing

CS2040 Data Structures and Algorithms

Lecture Note #2

Abstract Data Type

Outline

1. Abstract Data Type
   - 1.1 Data Structure
   - 1.2 Understanding ADT
2. Java Interface
   - 2.1 Using Java interface to define ADT
   - 2.2 Making an interface → FracADT Interface
   - 2.3 Fraction class: Variable based Implementation
   - 2.4 FractionArr class: Array based Implementation

1 Abstract Data Type

Collection of data + set of operations on the data

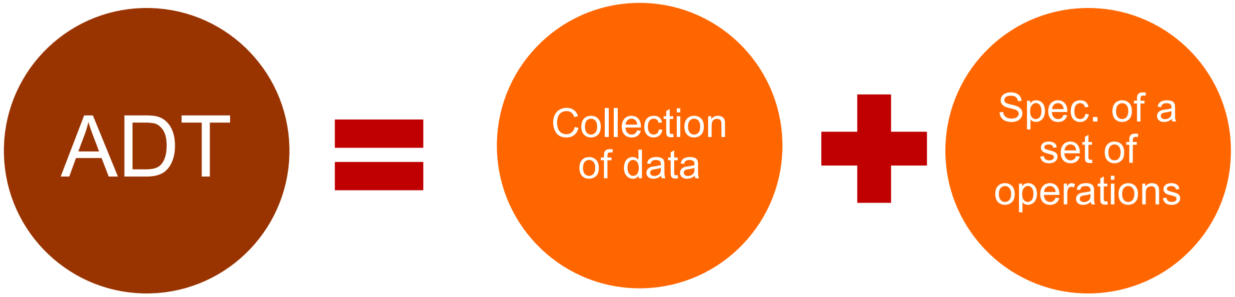
1.1 Data Structure

- Data structure is a construct that can be defined within a programming language to store a collection of data
  - Arrays, which are built into Java, are data structures
  - We can create other data structures. For example, we want a data structure (a collection of data) to store both the names and salaries of a collection of employees

```
class Employee {
   public static final int MAX_NUMBER = 500;
   public String name;
   public double salary;
   …
}
…
Employee[] workers = new Employee[Employee.MAX_NUMBER];
```

1.2 Abstract Data Type (ADT) (1/4)

- An **ADT** represent a collection of data together with a specification of a set of operations (functional abstraction) on the data
  - Functional abstraction → The specifications indicate **what** ADT operations do, ***not*** **how** to implement them
  - Also does not specify how the data is to be stored



ADT

Collection of data

Spec. of a set of operations

- **Data structures/algorithms** is then the **how to implement them** part

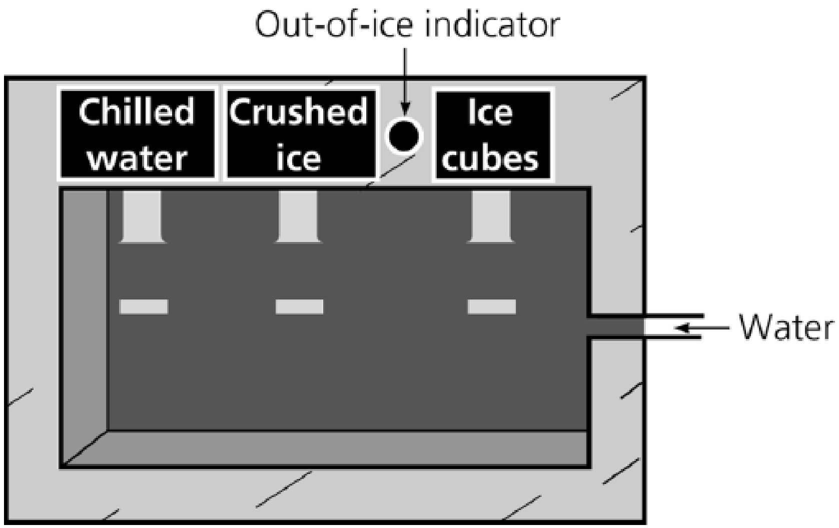
1.2 Abstract Data Type (ADT) (2/4)

- When a program needs data operations that are not directly supported by a language, you need to create your own ADT
- You should first design the ADT by carefully specifying the operations before implementation

1.2 Abstract Data Type (ADT) (3/4)

- Example: A water dispenser as an ADT
  - Data: water
  - Operations: *chill*, *crush*, *cube*, and *isEmpty*
  - Data structure: the internal structure of the dispenser
  - Walls: made of steel

    The only slits in the walls:
    - □ **Input: water**
    - □ **Output: chilled water, crushed ice, or ice cubes.**

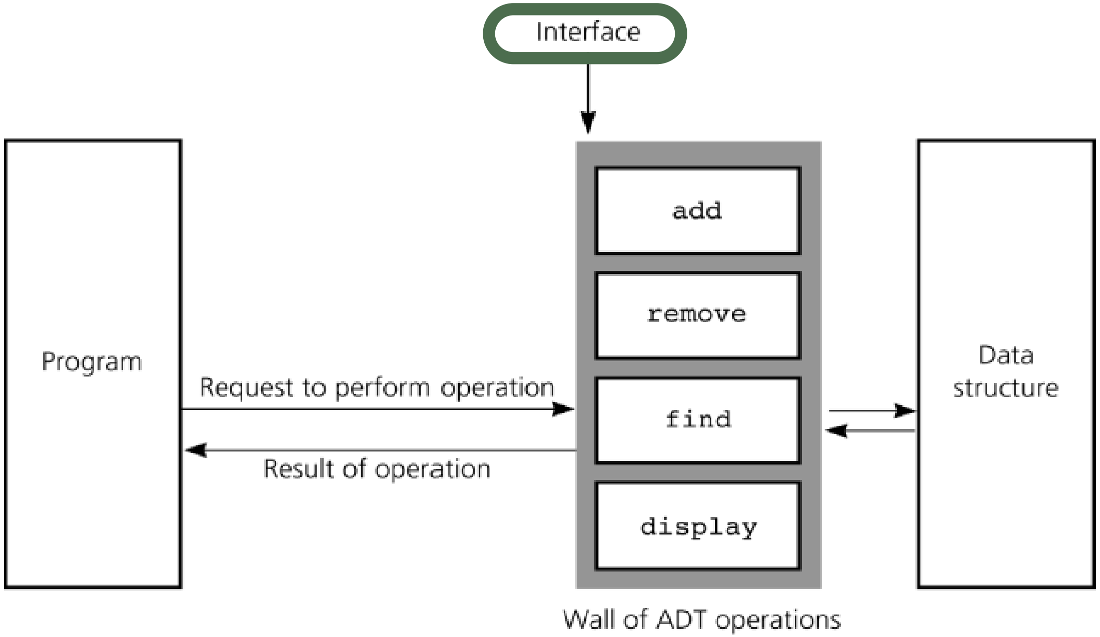


Crushed ice can be made in many ways.
We don't care how it was made

  - Using an ADT is like using a vending machine.

1.2 Abstract Data Type (ADT) (4/4)

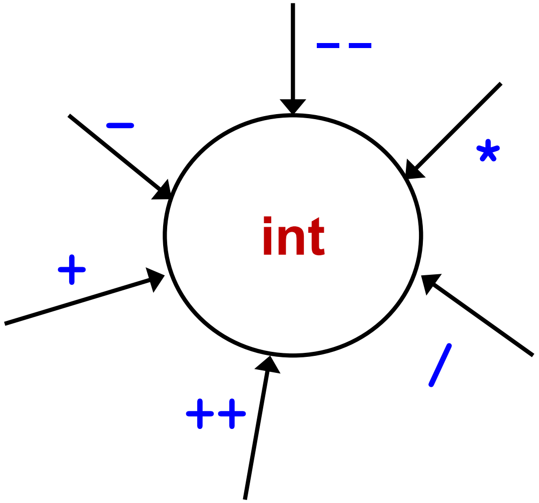
- A WALL of ADT operations hides a data structure from the program that uses it
- An interface is what a program/module/class should understand on using the ADT



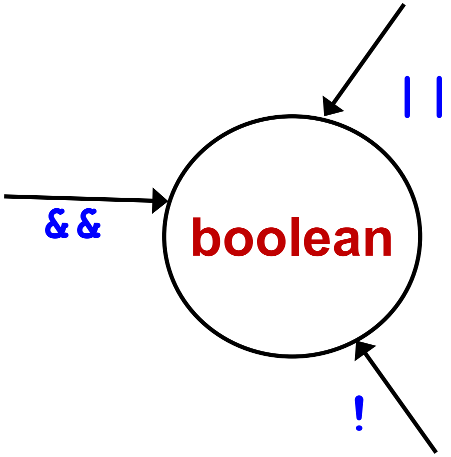
- This is like you reading and using the Java API

Eg: Primitive Types as ADTs (1/2)

- Java’s predefined data types are ADTs
- Representation details are hidden which aids ease of usage and portability
- Examples: int, boolean, double



int type with the operations (e.g.: --, /) defined on it.



boolean type with the operations (e.g.: &&) defined on it.

2 Java Interface

Specifying related methods

2.1 Java Interface to define ADT

- Java interfaces provide a way to specify a common set of operations for possibly unrelated classes and can be used to specify an ADT
- Java interface
  - uses the keyword **interface**, rather than **class**
  - specifies methods to be implemented
    - A Java interface is a group of related methods with empty bodies (before Java 8 …)
  - can have constant definitions (which are implicitly public static final)
- A class is said to implement the interface if it provides implementations for **ALL** the methods in the interface

2.2 Making an Interface → FracADT

- There can be many ways to implement class representing a positive fraction
- We can make it an ADT by specifying an interface
- Let’s call the interface FracADT (the design here makes implementations of FracADT immutable classes)

FracADT.java

```java
public interface FracADT {
   public int getNum();   //returns numerator part
   public int getDenom();   //returns denominator part
   public void setNum(int iNum);  //sets new numerator
   public void setDenom(int iDenom);  //sets new denominator

   public FracADT add(FracADT f);    //returns this + f
   public FracADT minus(FracADT f);  //returns this - f
   public FracADT times(FracADT f);  //returns this * f
   public FracADT divide(FracADT f);  //returns this / f
   public FracADT simplify(); //returns simplified version
}
```

2.3 Implementing the FracADT

- Two possible ways of implementing it
  - Using 2 variable to store the numerator/denominator (we have done this)
  - Using an array of size 2 to store the numerator/denominator
- This results in two possible classes

2.3 Fraction class – variable based (1)

- Skeleton program for Fraction.java

Fraction.java

```
class Fraction implements FracADT {
  public int num;
  public int denom;

  // Constructors
  public Fraction() {
    this(1,1); // calls the other constructor
  }
  public Fraction(int iNum, int iDenom) {
    setNum(iNum);
    setDenom(iDenom);
  }

  // Accessors
  public int getNum() { return num; }
  public int getDenom() { return denom;}

  // Mutators
  public void setNum(int iNum) { num = iNum;}
  public void setDenom(int iDenom) { denom = iDenom; }
```

2.3 Fraction class – variable based (2)

Fraction.java

```
  // Fill in the code for all the methods below
  public FracADT simplify() {
    int divisor = gcd(num,denom);
    Fraction result = new Fraction(num/divisor,denom/divisor);

    return result;
  }
  public FracADT add(FracADT f) { /* fill in the code */}
  public FracADT minus(FracADT f) { /* fill in the code */}
  public FracADT times(FracADT f) { /* fill in the code */}
  public FracADT divide(FracADT f) { /* fill in the code */}

  // Overriding methods toString() and equals()
  public String toString() { /* fill in the code */}
  public boolean equals(Object obj) { /* fill in the code */}

  // Returns greatest common divisor of a and b
  public static int gcd(int a, int b) { /* fill in the code */}
}
```

2.4 FractionArr class – Array based

- Skeleton program for FractionArr.java

FractionArr.java

```
class FractionArr implements FracADT {
  public int[] members; // index 0 is num, index 1 is denom
  public static final int num = 0;
  public static final int denom = 1;

  //Constructor – note we don’t have the default constructor here
  public FractionArr(int iNum, int iDenom) {
    members = new int[2];
    setNum(iNum);
    setDenom(iDenom);
  }

  // Accessors
  public int getNum() {return members[num];}
  public int getDenom() {return members[denom];}

  // Mutators
  public void setNum(int iNum) {members[num] = iNum;}
  public void setDenom(int iDenom) {members[denom] = iDenom;}

  // The rest are omitted here
}
```

Interface can be used as a type

- Each interface is compiled into a separate bytecode file, just like a regular class
  - We cannot create an instance of an interface, but we can use an interface as a data type for a variable, or as a result of casting

```
public boolean equals (Object obj) {
  if (obj instanceof FracADT) {
     FracADT temp1 = ((FracADT) obj).simplify(); // result of casting
     FracADT temp2 = simplify();
     return ((temp1.getNum() == temp2.getNum()) &&
             (temp1.getDenom() == temp2.getDenom()));
  }
  return false;
}
```

Summary

- We learn about the need for ADTs
- We learn about using Java Interface to define an ADT
- With this, we will learn and define various kinds of ADTs/data structures in subsequent lectures

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