NUS National University of Singapore

School of Computing

CS2040S Data Structures and Algorithms

Lecture Note #2

Abstract Data Type

Outline

1. Abstract Data Type
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1 Abstract Data Type

Collection of data + set of operations on the data

1.1 Data Structure (1)

- 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, our fraction class from lecture 1 is a data structure.

```
class FractionV1 {
  public int num, denom;

  public FractionV1(int iNum, int iDenom) {
    num = iNum;
    denom = iDenom;
  }

  public int getNum() { return num; }
  public int getDenom() { return denom; }
  …
}
…
FractionV1[] fList = new FractionV2[100];
```

1.1 Data Structure (2)

- We can also implement a fraction differently as follows:

```
class FractionV2 {
  public int[] members; // index 0 is num, index 1 is denom
  public static final int num = 0;
  public static final int denom = 1;

  public FractionV2(int iNum, int iDenom) {
    members = new int[2];
    members[num] = iNum;
    members[denom] = iDenom;
  }

  public int getNum() { return members[num]; }
  public int getDenom() { return members[denom]; }
  …
}
```

1.1 Data Structure (3)

- Even though both FractionV1 and FractionV2 implement the same entity which is a Fraction we cannot do the following

```
FractionV1 f1 = new FractionV1(1,2);
FractionV2 f2 = f1; // ← Compilation error here
```

- Since they are two different data types.

1.2 Abstract Data Type (ADT)

- An Abstract Data Type (**ADT**) is then looking at data types independent of the implementation details
- An **ADT** represent a collection of data together with a specification of a set of operations (functional abstraction) on the data
  - Functional abstraction → Indicate **what** ADT operations do, ***not* how** to implement them
  - Also does not specify how the data is to be stored

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

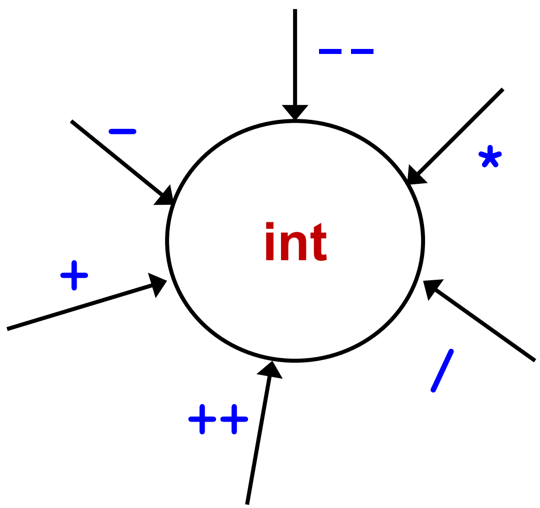
Real Life Analogy of ADT

All cars have a common interface

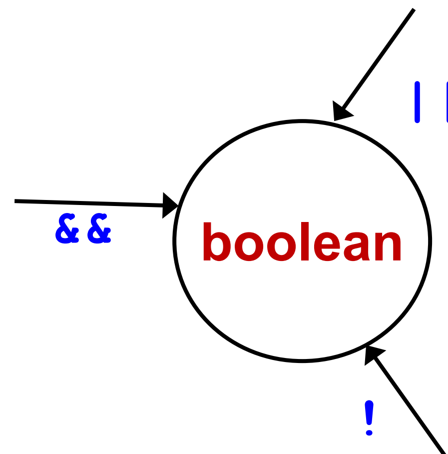
- Steering wheel
- Gear box (manual or auto)
- Pedals (acceleration, brake, clutch)
- …

Primitive Types as ADTs

- Java's predefined data types can be viewed as 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

```
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
}
```

2.5 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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