

4. Writing Classes

- Objectives - when we have completed this set of notes, you should be familiar with:
 - Anatomy of a class: state and behaviors
 - Constructors
 - UML class diagrams
 - Encapsulation
 - Anatomy of a method: Parameters, Local data
 - Constant fields (public and private)
 - Invoking methods in the same class
 - Building a class incrementally
 - Testing a class in Interactions
 - Writing a driver program



Writing Classes

- Thus far you have written programs that use classes defined in the Java standard class library
- The driver program, which has the main method, should not contain all of your code
- Object-oriented programming:
 - Classes define sets of objects that will hold data and have specified behavior
 - Each class should be contained a separate file
 - Separate files facilitate testing



Classes and Objects

- An object has a state and behaviors
 - You have used the Scanner class (from the Java API) to create a Scanner object

```
Scanner input = new Scanner(System.in);
```

- It's **state** includes the "target" for the Scanner object (e.g., System.in); the input/data being "scanned"
- It's **behaviors** include reading the next int, reading the next line, etc.

```
input.nextInt(); input.nextLine();
```



Classes and Objects

- Consider a six-sided die (singular of dice)
- Its state might include a face value (in the range 1 to 6 inclusive currently showing)
- Its behaviors might include...
 - roll (roll the die to a random value 1 - 6)
 - setFaceValue (set the die to a specified value 1 - 6)
 - getFaceValue (get the face value)

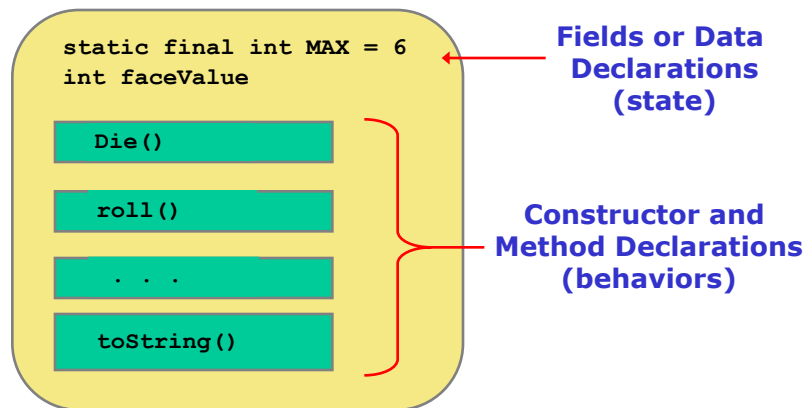
- Example of how the Die class could be used:

```
Die dieObj = new Die();  
dieObj.roll();  
int rollResult = dieObj.getFaceValue();
```



Classes

- We need a Die class with a constant and instance data for state and methods for the behaviors



Classes

- You can now create multiple dice in one program
- A program will not necessarily use all aspects of a given class
- Consider [RollingDice.java](#) and [Die.java](#) (from Lewis and Loftus textbook)



The Die Class

- The `Die` class contains two fields (or data declarations)
 - a constant `MAX` that represents the maximum face value
 - an integer `faceValue` that represents the current face value
- The `roll` method uses the `random` method of the `Math` class to determine a new face value
- There are also methods to explicitly set and retrieve the current face value at any time



The toString Method

- All classes that represent objects should declare a `toString` method
- The `toString` method returns a `String` that represents the object in some way
 - Called automatically anytime the object is referenced where a `String` is needed (e.g., when concatenated to a string or when it is passed to the `println` method)
 - In the jGRASP Interactions pane, `toString` is called automatically when an object reference is evaluated as an expression (e.g., if `die1` is a reference for a `Die` object, then entering `die1` in interactions evaluates to the result of its `toString` method)



Constructors

- A *constructor* is called by the `new` operator to create an object and set its initial state. It looks similar to a method but has the same name as the class and has no return type
- A constructor may or may not have parameters. A class may have multiple constructors if the parameters differ by number, type, and/or order
- The `Die` constructor has no parameters but sets the initial face value of each new die object to one



Data Scope

- The *scope* of data (variables) is the enclosing context/block (i.e., `{ }`) in a program where that data can be referenced (used)
- *Instance data* (fields declared at the top of the class) can be referenced by all methods in that class; scope in instance data is the entire class
- *Local data* (declared inside of a method) can only be used within that method
 - Example: In the `Die` class, the variable `result` is declared inside the `toString` method -- it is local to that method and cannot be referenced anywhere else



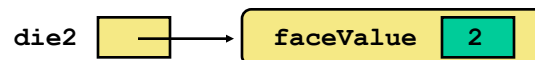
Instance Data

- The `faceValue` variable in the `Die` class is called *instance data* because each instance (object) that is created has its own version of it
- The declaration of an instance variable specifies the type of the data, but it does not reserve any memory space for it
- Each time a `Die` object is created using the `new` operator and constructor, a new `faceValue` variable is created within the object
- All objects of a class will use the same methods in the class, but each object has its own data space for instance variables



Instance Data

- We can depict the two `Die` objects from the `RollingDice` program as follows:



Each object maintains its own `faceValue` variable, and thus its own state

- jGRASP – Die objects on canvas in Basic viewer:



Q1



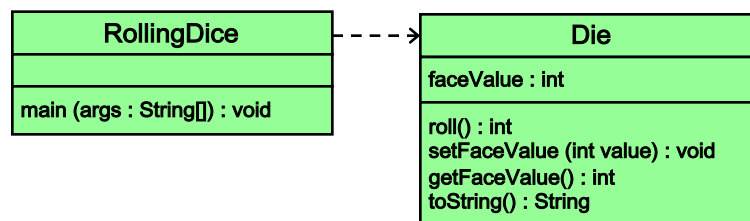
UML Class Diagrams

- UML stands for the *Unified Modeling Language*
- UML *class* diagrams show relationships among classes in the program
- A UML *class diagram* consists of one or more classes; a simple diagram has only the class name whereas a detailed diagram also has sections for the attributes (data) and operations (methods)
- Lines between classes represent *associations*; A dashed line arrow shows that one class *uses* the other (e.g., calls its methods)



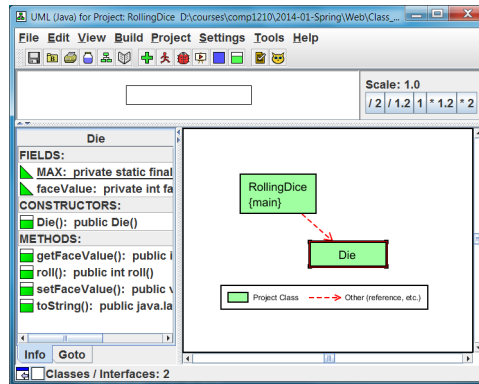
UML Class Diagrams

- A UML class diagram for the `RollingDice` program:



UML Class Diagrams in jGRASP

- Generate UML Class Diagram
- Select the Die class
- Right-click, select "Show Class Info"
- Info tab shows fields, constructors, and methods



Encapsulation

- A client (program) can access and modify object's state through it's methods. Example:

```
dieObj.setFaceValue(6);
```



- We should make it difficult, if not impossible, for a client to access an object's variables directly

```
dieObj.faceValue = 6;
```

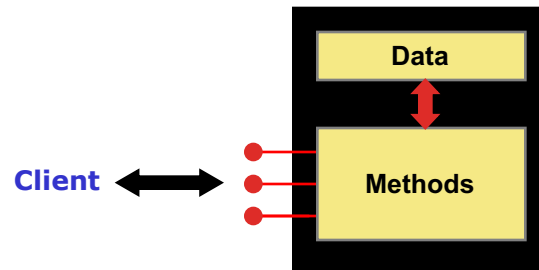


- The second line should cause a compile-time error; otherwise, the class violates *encapsulation*



Encapsulation

- An encapsulated object can be thought of as a *black box* -- its inner workings are hidden from the client
- The client invokes the interface methods of the object, which manages the instance data



Access (Visibility) Modifiers

- How do we make sure not to violate encapsulation?
- *Access modifiers* define who can access an instance variable or a method
- Java has three access modifiers:
`public`, `protected`, and `private`
- The `protected` modifier involves inheritance, which we will discuss later
- The fields, constructors, and methods of a classes (collectively called *members* of the class) can each have an access modifier



Access (Visibility) Modifiers

- Members of a class that are declared with **public** access can be referenced anywhere
 - public instance variables violate encapsulation
- Members of a class that are declared with **private** access can be referenced only within that class
 - For now, all instance variables should be private
- Members declared with no access modifier have *default* access - - can be referenced by classes in the same package (or by classes in the same folder if classes are not in a declared package)
- See textbook for more information



Access (Visibility) Modifiers

- *Service methods* are public methods that offer useful behaviors to the client
- *Support methods* are declared as private and can only be used by other methods in the class
 - Sometimes methods get too large or multiple methods need to use the same code
 - Solution: create a private method for use by other methods in the class (e.g., calculations needed by several methods could be placed in a separate method)
- The Java API shows only public members (fields, constructors, and methods)



Access (Visibility) Modifiers

| | public | private |
|--------------------|-----------------------------|------------------------------------|
| Instance Variables | Violate encapsulation | Enforce encapsulation |
| Methods | Provide services to clients | Support other methods in the class |

[Q2](#)



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Accessors and Mutators

- Because instance data is private, a class has methods to access and modify data values
- An *accessor method* returns the current value of a variable (sometimes called a “getter”)
 - Example: `getFaceValue` in `Die`
- A *mutator method* changes the value of a variable (sometimes called a “setter”)
- Example: `setFaceValue` in `Die`
- The names of accessor and mutator methods usually take the form `getX` and `setX`, respectively, where `x` is the name of the field



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Mutator Restrictions

- Choose carefully which variables have getter and setter methods
 - While many classes that you write will have at least some getter and setter methods, others may not have any
 - Sometimes you don't want the user to be able to get or set fields, so no accessor or mutator methods are provided (e.g., the String and Scanner classes have no getters or setters)
- Use if-else statements (CN 2, 5) to to set mutator restrictions on fields (e.g., a field can only take on values in specified range)



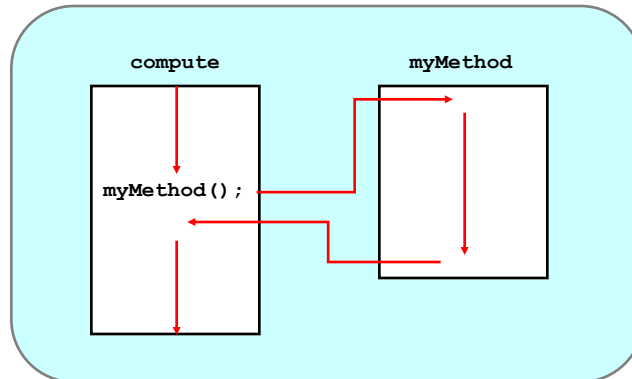
Method Declarations

- A *method declaration* specifies the code that will be executed when the method is invoked (called)
- When a method is invoked, the flow of control jumps to the method and executes its code
- When complete, the flow returns to the place where the method was called and continues
- The invocation may or may not return a value, depending on how the method is defined



Method Control Flow

- If the called method is in the same class, only the method name is needed



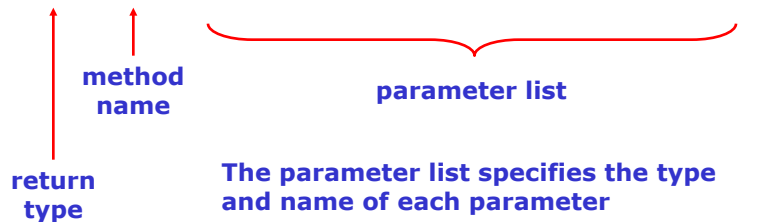
In the debugger, "Step-In" to the called method



Method Header

- The first part of the method declaration is commonly called the *method header*

```
public char calc(int num1, int num2, String message)
```



The parameter list specifies the type and name of each parameter

The name of a parameter in the method declaration is called a *formal parameter*




Method Body

- The method header is followed by the *method body*

```
public char calc (int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt(sum);

    return result;
}
```

The return expression
must be consistent with
the return type

sum and result
are local data

They are created
each time the
method is called, and
are destroyed when
it finishes executing



The return Statement

- The **return type** of a method indicates the type of value that the method sends back to the calling location
- A method with a **void** return type returns no value
- A **return statement** specifies the value that will be returned

`return expression;`


Q3



Parameters

- When a method is called, the values of *actual parameters* [arguments] in the invocation are copied into the *formal parameters* of the method (i.e., parameters are passed by value)

```
ch = obj.calc (4, count, "War Eagle!");
```



The diagram illustrates the passing of arguments by value. Red arrows originate from the arguments in the invocation: the first arrow from '4' points to the 'int num1' parameter; the second arrow from 'count' points to the 'int num2' parameter; and the third arrow from '"War Eagle!'" points to the 'String message' parameter. This visualizes how the values are copied into the method's formal parameters.

```
public char calc (int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt (sum);

    return result;
}
```

[MethodExample.java](#)



Local Data


- As we've seen, local variables can be declared inside a method
- The formal parameters of a method create *automatic local variables* when the method is invoked
- When the method finishes, all local variables are destroyed (including the formal parameters)
- Keep in mind that instance variables, declared at the class level, exists as long as the object exists (i.e., a variable references the object)



Constructors Revisited

- Note that a constructor has no return type specified in the method header, not even `void`
- A common error is to put a return type on a constructor, which makes it a “regular” method that happens to have the same name as the class
- If the programmer does not define a constructor, then the class has a *default constructor* that accepts no parameters

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- ### Q4

Constant Fields

- Recall that a class constant can be declared as follows:

```
private static final int MAX_AMOUNT = 5;
```

 - Uses the static and final reserved words (static will be covered in detail later in the course)
 - The name is in all caps with words separated by _
- In general, you do not want “magic numbers” (literal values) in your code

Replace this code: `if (number > 5) . . .`

With this code: `if (number > MAX_AMOUNT)`
 `. . .`

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- With this code:**
- ```
if (number > MAX_AMOUNT)
 ...
```



## Constant Fields

- Unlike variables, constants can be public without violating encapsulation.
  - For example, the PI constant in the Math class

```
double circumference = Math.PI * diameter;
```
  - Referenced by using the name of the class, the dot operator, and the name of the constant
  - When you define a constant inside your own class, you can reference it inside the class without using the class name

```
if (number > MAX_AMOUNT) . . .
```



## Constant Fields

- Suppose the Student class had two types of students: undergrad and graduate

```
public static final int GRADUATE = 0, UNDERGRAD = 1;
```
- Now client programs can set student type using constants (studentObj is an instance of Student):

**Replace this code:**

```
studentObj.setStudentType(0);
```

**With this code:**

```
studentObj.setStudentType(Student.GRADUATE);
```



## Building a Class

- Suppose you wanted to create a class called Loan representing a loan with a balance, interest, and maximum loan amount
  - The balance starts at 0
  - The interest is 0.05 unless set otherwise
  - There are two loan types: employees and customers
  - Employees can borrow up to \$100,000
  - Customers can borrow up to \$10,000
- Create the empty class (then save and compile)

```
public class Loan {
}
```



## Building a Class: Variables

- Add instance variables to the class. Take another look at the class description:
  - Suppose you wanted to create a class called Loan representing a loan with a **balance**, **interest**, and **maximum loan amount**
    - **The balance starts at 0**
    - The interest is 0.05 unless set otherwise
    - There are two loan types: employees and customers
    - Employees can borrow up to \$100,000
    - Customers can borrow up to \$10,000

```
// Fields - instance variables
private double balance = 0;
private double interestRate;
private double maxLoanAmount;
```



## Building a Class: Constants

- Look for values that could be represented as constants:
    - **The interest rate is 0.05 unless set to another non-negative value**
    - There are two loan types: employees and customers
    - **Employees can borrow up to \$100,000**
    - **Customers can borrow up to \$10,000**
- The default interest rate and maximum loan amounts will be important for the class, but won't be needed by client programs. Therefore, the constants are private.

*// Fields - Constants*

```
private static final double DEFAULT_INTEREST = 0.05;
private static final double CUSTOMER_MAX = 10000;
private static final double EMPLOYEE_MAX = 100000;
```



## Building a Class: Constants

- Look for values that could be represented as constants:
  - The interest is 0.05 unless set otherwise
  - **There are two loan types: employees and customers**
  - Employees can borrow up to \$100,000
  - Customers can borrow up to \$10,000

The loan type (customer or employee) will be set in the constructor using an int value. It would therefore be useful to provide constants for the client program:

```
public static final int EMPLOYEE_ACCOUNT = 0;
public static final int CUSTOMER_ACCOUNT = 1;
```



## Building a Class: Constructor

- The constructor for the bank class should take **an int parameter** representing the type of loan (employee or customer)
- Create an empty constructor; you will fill in the code later:

```
public class Loan {
 /* ... Fields go here ... */
 public Loan(int accountType) {
 }
}
```



## Building a Class: Methods

- Create a skeleton (stub) method for each of the following methods, *or if simple, just complete the method*:

- A 'getter' method for the balance returns a double:

```
public double getBalance() {
 return balance;
}
```

- A 'setter' method for the interest rate (a double) that returns true and sets the interest only if the interest is from 0 to 1:

```
public boolean setInterestRate(double interestRateIn) {
 return false;
}
```



## Building a Class: Methods

- Create a skeleton (or stub) method for each of the following additional methods:

- borrow: adds an additional amount to the loan and returns true only if the loan stays below the maximum amount.

```
public boolean borrow(double amount) {
 return false;
}
```

- totalBalance: returns a double representing the loan amount with the interest added.

```
public double totalBalance() {
 return 0.0;
}
```



## Building a Class

- You can now compile your program with empty methods. See the [Loan class in examples/method stubs](#) for an example.
- This is the point where you could submit your project to a Skeleton Code assignment in Web-CAT, if there is one.
  - A Skeleton Code assignment is intended to check class and method names as well method return types and parameters; correctness is not checked.



## Building a Class: Constructor

- The constructor should set the interest rate to the default interest and then set the maximum loan amount based on the parameter.

```
public Loan(int accountType) {
 interestRate = DEFAULT_INTEREST;
 if (accountType == EMPLOYEE_ACCOUNT) {
 maxLoanAmount = EMPLOYEE_MAX;
 }
 else {
 maxLoanAmount = CUSTOMER_MAX;
 }
}
```

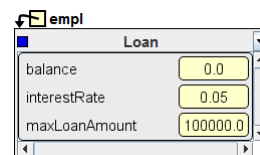
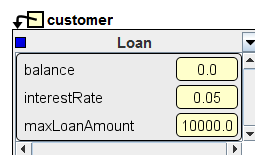


## Building a Class: Constructor

- To test your constructor, instantiate objects in the interactions pane and check the values of the instance variables in the workbench.

```
Loan customer = new Loan(Loan.CUSTOMER_ACCOUNT);
```

```
Loan empl = new Loan(Loan.EMPLOYEE_ACCOUNT);
```



## Building a Class: Methods

- You can now complete your `getBalance` method and `setInterest` method.
  - In general, **get methods will not change the state of the object**, but will only return a value. [recall, we already completed it]
  - Set methods will often have a boolean return type to indicate if the inputs are valid and the method actually “set” the field.
  - Test each one of your methods as you create them. You can view each method’s effect on instance variables using interactions and the workbench.



## Building a Class: Testing

- Example: Test both the function and the return of the `setInterest` method (workbench and interactions).

```
▶ Loan loanObj = new Loan(Loan.CUSTOMER_ACCOUNT);
▶ loanObj.setInterestRate(-1)
 false
▶ loanObj.setInterestRate(2)
 true
▶ loanObj.setInterestRate(0.5)
 true
```

See the completed Loan class in [Loan.java](#)



## Repeated Code

- In general, you do not want to repeat calculations in your code.
  - The toString method should return a string that includes the total balance.
  - In this case, make a call to the method that performs the calculation:

```
public String toString() {
 DecimalFormat df1 = new DecimalFormat("$#,##0.00");
 DecimalFormat df2 = new DecimalFormat("#0.0%");
 String output = "Loan amount: "
 + df1.format(balance) + "\n"
 + "Total balance with " + df2.format(interestRate)
 + " interest: " + df1.format(totalBalance())
 + "\n";
 return output;
}
```



## Driver Program

- The Loan class cannot be run as an application, but can only be used by other programs.
- In this case, we might want to create a driver program that users can execute to set up a loan, borrow an amount, and view their balance.
- See [LoanCalculator.java](#) for an example of a driver program for the Loan class.





# Summary

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  - Anatomy of a class: state and behaviors
  - Constructors
  - UML class diagrams
  - Encapsulation
  - Anatomy of a method: Parameters, Local data
  - Constant fields (public and private)
  - Invoking methods in the same class
  - Building a class incrementally
  - Testing a class in Interactions
  - Writing a driver program

