

CSC 222: Object-Oriented Programming

Fall 2015

interacting objects

- abstraction, modularization
- internal vs. external method calls
- expressions, type casting
- primitives vs. objects
- modular design: dot races
- static fields, final static fields
- private (helper) methods

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Abstraction

abstraction is the ability to ignore details of parts to focus attention on a higher level of a problem

- note: we utilize abstraction everyday
do you know how a TV works? could you fix one? build one?
do you know how an automobile works? could you fix one? build one?

abstraction allows us to function in a complex world

- we don't need to know how a TV or car works
- must understand the controls (*e.g., remote control, power button, speakers for TV*)
(*e.g., gas pedal, brakes, steering wheel for car*)
- details can be abstracted away – not important for use

the same principle applies to programming

- we can take a calculation/behavior & implement as a method
after that, don't need to know how it works – just call the method to do the job
- likewise, we can take related calculations/behaviors & encapsulate as a class

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Abstraction examples

recall the Die class

- included the method `roll`, which returned a random roll of the Die

do you remember the formula for selecting a random number from the right range?

WHO CARES?!? Somebody figured it out once, why worry about it again?

SequenceGenerator class

- included the method `randomSequence`, which returned a random string of letters

you don't know enough to code it, but you could use it!

Circle, Square, Triangle classes

- included methods for drawing, moving, and resizing shapes

again, you don't know enough to code it, but you could use it!

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Modularization

modularization is the process of dividing a whole into well-defined parts, which can be built and examined separately, and which interact in well-defined ways

- early computers were hard to build – started with lots of simple components (e.g., vacuum tubes or transistors) and wired them together to perform complex tasks
- today, building a computer is relatively easy – start with high-level modules (e.g., CPU chip, RAM chips, hard drive) and plug them together

the same advantages apply to programs

- if you design and implement a method to perform a well-defined task, can call it over and over within the class
- likewise, if you design and implement a class to model a real-world object's behavior, then you can reuse it whenever that behavior is needed (e.g., Die for random values)

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Code reuse can occur within a class

one method can call another method

- a method call consists of method name + any parameter values in parentheses (as shown in BlueJ when you right-click and select a method to call)

```
this.methodName(paramValue1, paramValue2, ...);
```

- calling a method causes control to shift to that method, executing its code
- if the method returns a value (i.e., a return statement is encountered), then that return value is substituted for the method call where it appears

```
public class Die {  
    ...  
  
    public int getNumberOfSides() {  
        return this.numSides;  
    }  
  
    public int roll() {  
        this.numRolls++;  
        return (int)(Math.random()*this.getNumberOfSides() + 1);  
    }  
}
```

here, the number returned by the call to `getNumberOfSides` is used to generate the random roll

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Internal calls

when a constructor/method calls another method from within the same object, we call that an *internal* method call

```
public class HoopsScorer{  
    ...  
  
    public HoopsScorer() {  
        this.reset();  
    }  
  
    public void reset() {  
        this.score = 0;  
        this.numMade3 = 0;  
        this.numMissed3 = 0;  
        .  
        .  
        .  
    }  
}
```

- for HW1: modified the `HoopsScorer` constructor so that it simply called `reset`
- that way, did not have to duplicate all of the initialization/reset assignments

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Expressions and types

in general, Java operations are *type-preserving*

- if you add two `ints`, you get an `int` $2 + 3 \rightarrow 5$
- if you add two `doubles`, you get a `double` $2.5 + 3.5 \rightarrow 6.0$
- if you add two `Strings`, you get a `String` $"foo" + "2u" \rightarrow "foo2u"$

this applies to division as well

- if you divide two `ints`, you get an `int` – any fractional part is discarded!

$8/4 \rightarrow 2$ $9/4 \rightarrow (2.25) \rightarrow 2$ $-9/4 \rightarrow (-2.25) \rightarrow -2$
 $1/2 \rightarrow ???$ $999/1000 \rightarrow ???$ $x/(x+1) \rightarrow ???$

for mixed expressions, the more specific value is converted first

$3.2 + 1 \rightarrow (3.2 + 1.0) \rightarrow 4.2$
 $"x = " + 5 \rightarrow "x = " + "5" \rightarrow "x = 5"$

FYI: the `%` operator gives the remainder after performing `int` division

$12 \% 2 \rightarrow 0$ $13 \% 2 \rightarrow 1$ $18 \% 5 \rightarrow ???$

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int vs. real division

must be very careful when dividing `int` values

```
double percent = this.numCorrect/this.numGuesses;
```

Solution 1: declare the fields to be `double` instead of `int`

KLUDGY! if a value is an integer, declare it to be an `int`!

Solution 2: introduce a real value into the equation

```
double percent = 1.0*this.numCorrect/this.numGuesses;
```

SLIGHTLY LESS KLUDGY! raises questions in the reader's mind

Solution 3: cast (convert) one of the `int` values into a `double` (NEWTYPE) VALUE

```
double percent = (double)this.numCorrect/this.numGuesses;
```

GOOD! makes the type conversion clear to reader

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Primitive types vs. object types

primitive types are predefined in Java, e.g., `int`, `double`, `boolean`

object types are those defined by classes, e.g., `Circle`, `Die`

- so far, our classes have utilized primitives for fields/parameters/local variables
- as we define classes that encapsulate useful behaviors, we will want build on them

when you declare a variable of primitive type, memory is allocated for it

- to store a value, simply assign that value to the variable

```
int x;                                double height = 72.5;
x = 0;
```

when you declare a variable of object type, it is NOT automatically created

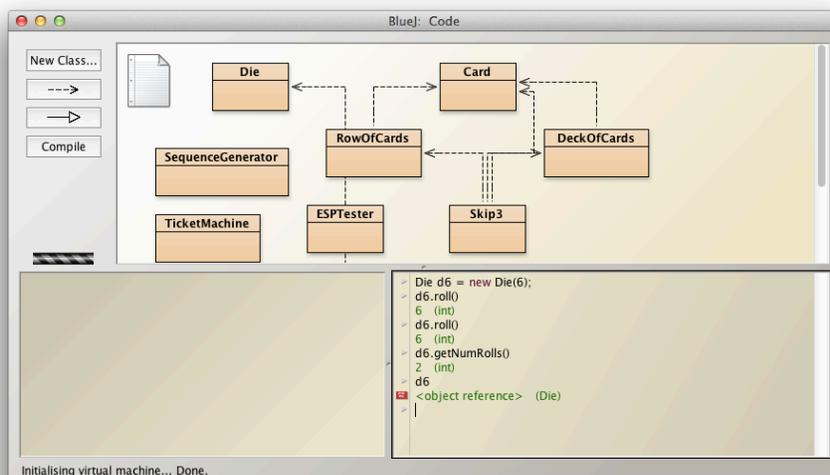
- to initialize, must call its constructor: `OBJECT = new CLASS (PARAMETERS) ;`
- to call a method: `OBJECT.METHOD (PARAMETERS)`

```
Circle circle1;                       Die d8 = new Die(8);
circle1 = new Circle();                System.out.println( d8.roll() );
circle1.changeColor("red");
```

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BlueJ's code pad

the code pad allows you to enter Java statements to create objects and call methods on those objects



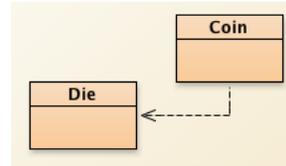
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Coin class

we can define classes with fields that are objects of other classes

- Coin class has a 2-sided Die as a field
- Coin constructor must construct the Die object to initialize that field
- flip method makes an *external method call* on the Die object

suppose we wanted to add a `getNumFlips` method?



```
public class Coin {
    private Die d2;

    public Coin() {
        this.d2 = new Die(2);
    }

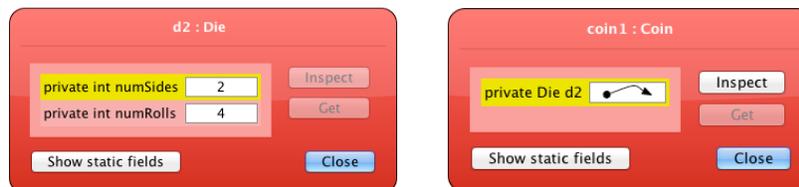
    public String flip() {
        int rollResult = this.d2.roll();
        if (rollResult == 1) {
            return "HEADS";
        }
        else {
            return "TAILS";
        }
    }
}
```

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primitive types vs. object types

internally, primitive and reference types are stored differently

- when you inspect an object, any primitive fields are shown as boxes with values
- when you inspect an object, any object fields are shown as pointers to other objects



- of course, you can further inspect the contents of object fields

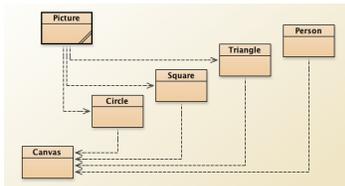
we will consider the implications of primitives vs. objects later

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House example

recall the picture of a house

- involved creating 4 shapes & adjusting their colors, sizes & positions
- instead of doing this manually through BlueJ, we could define a class that automates these steps
- the `Picture` class has fields for each of the shapes in the picture
- in the `draw` method, each shape is created (by calling its constructor) and adjusted (by calling methods)



```
public class Picture {
    private Square wall;
    private Square window;
    private Triangle roof;
    private Circle sun;

    public Picture() {
        this.wall = new Square();
        this.window = new Square();
        this.roof = new Triangle();
        this.sun = new Circle();
    }

    public void draw() {
        this.wall.moveVertical(80);
        this.wall.changeSize(100);
        this.wall.makeVisible();

        this.window.changeColor("black");
        this.window.moveHorizontal(20);
        this.window.moveVertical(100);
        this.window.makeVisible();

        this.roof.changeSize(50, 140);
        this.roof.moveHorizontal(60);
        this.roof.moveVertical(70);
        this.roof.makeVisible();

        this.sun.changeColor("yellow");
        this.sun.moveHorizontal(180);
        this.sun.moveVertical(-10);
        this.sun.changeSize(60);
        this.sun.makeVisible();
    }
}
```



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HW2:

in-class exercises:

- modify the `PairOfDice` class, which has two `Die` objects as fields
- when you roll a pair, you get a `String`, e.g., "4-3"
- work on the extensions in class (with a partner if you choose)

individual homework:

- design a class from scratch for playing a guessing game
- a `GuessingGame` object picks a random `int` from a range
 - ✓ the `makeGuess` method takes a `guess` as parameter and returns a message, e.g., "50 is too high. Guess again..."
 - ✓ other methods allow you to determine the number of guesses and to reset
- your class must meet the specifications of [GuessingGame.html](#)
- you will use your class to answer some questions about the game

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Dot races

consider the task of simulating a dot race (as on stadium scoreboards)

- different colored dots race to a finish line
- at every step, each dot moves a random distance
- the dot that reaches the finish line first wins!

behaviors?

- create a race (dots start at the beginning)
- step each dot forward a random amount
- access the positions of each dot
- display the status of the race
- reset the race

we could try modeling a race by implementing a class directly

- store positions of the dots in fields
- have each method access/update the dot positions

BUT: lots of details to keep track of; not easy to generalize

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A modular design

instead, we can encapsulate all of the behavior of a dot in a class

Dot class: create a `Dot` (with a given color, maximum step size)
access the dot's position
take a step
reset the dot back to the beginning
display the dot's color & position

once the `Dot` class is defined, a `DotRace` will be much simpler

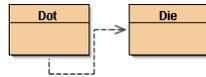
DotRace class: create a `DotRace` (with same maximum step size for both dots)
access either dot's position
move both dots a single step
reset both dots back to the beginning
display both dots' color & position

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Dot class

more naturally:

- fields store a Die (for generating random steps), color & position



- constructor creates the Die object and initializes the color and position fields
- methods access and update these fields to maintain the dot's state

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;

    public Dot(String color, int maxStep) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
    }

    public void step() {
        this.dotPosition += this.die.roll();
    }

    public void reset() {
        this.dotPosition = 0;
    }

    public int getPosition() {
        return this.dotPosition;
    }

    public void showPosition() {
        System.out.println(this.dotColor + ": " +
            this.dotPosition);
    }
}
```

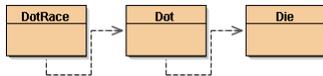
CREATE AND PLAY

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DotRace class

using the Dot class, a DotRace class is straightforward

- fields store the two Dots



- constructor creates the Dot objects, initializing their colors and max steps
- methods utilize the Dot methods to produce the race behaviors

```
public class DotRace {
    private Dot redDot;
    private Dot blueDot;

    public DotRace(int maxStep) {
        this.redDot = new Dot("red", maxStep);
        this.blueDot = new Dot("blue", maxStep);
    }

    public int getRedPosition() {
        return this.redDot.getPosition();
    }

    public int getBluePosition() {
        return this.blueDot.getPosition();
    }

    public void step() {
        this.redDot.step();
        this.blueDot.step();
    }

    public void showStatus() {
        this.redDot.showPosition();
        this.blueDot.showPosition();
    }

    public void reset() {
        this.redDot.reset();
        this.blueDot.reset();
    }
}
```

CREATE AND PLAY

ADD ANOTHER DOT?

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Adding a finish line

suppose we wanted to place a finish line on the race

- what changes would we need?

could add a field to store the goal distance

- user specifies goal distance along with max step size in constructor call
- step method would not move if either dot has crossed the finish line

```
public class DotRace {
    private Dot redDot;
    private Dot blueDot;
    private int goalDistance; // distance to the finish line

    public DotRace(int maxStep, int goal) {
        this.redDot = new Dot("red", maxStep);
        this.blueDot = new Dot("blue", maxStep);
        this.goalDistance = goal;
    }

    public int getGoalDistance() {
        return this.goalDistance;
    }

    . . .
}
```

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Adding a finish line

step method needs a 3-way conditional:

- either blue crossed or red crossed or the race is still going on

```
public void step() {
    if (this.getBluePosition() >= this.goalDistance) {
        System.out.println("The race is over!");
    }
    else if (this.getRedPosition() >= this.goalDistance) {
        System.out.println("The race is over!");
    }
    else {
        this.redDot.step();
        this.blueDot.step();
    }
}
```

ugly! we want to avoid
duplicate code

fortunately, Java provides *logical operators* for just such cases

(TEST1 || TEST2) evaluates to true if either TEST1 **OR** TEST2 is true

(TEST1 && TEST2) evaluates to true if either TEST1 **AND** TEST2 is true

(!TEST) evaluates to true if TEST is **NOT** true

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Adding a finish line

here, could use `||` to avoid duplication

- print message if *either* blue or red has crossed the finish line

```
public void step() {
    if (this.getBluePosition() >= this.goalDistance ||
        this.getRedPosition() >= this.goalDistance) {
        System.out.println("The race is over!");
    }
    else {
        this.redDot.step();
        this.blueDot.step();
    }
}
```

warning: the tests that appear on both sides of `||` and `&&` must be complete Boolean expressions

`(x == 2 || x == 12)` OK

`(x == 2 || 12)` BAD!

note: we could have easily written `step` using `&&`

- move dots if *both* blue and red dots have failed to cross finish line

```
public void step() {
    if (this.getBluePosition() < this.goalDistance &&
        this.getRedPosition() < this.goalDistance) {
        this.redDot.step();
        this.blueDot.step();
    }
    else {
        System.out.println("The race is over!");
    }
}
```

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Further changes

EXERCISE: make these modifications to your `DotRace` class

- add the `goalDistance` field
- modify the constructor to include the goal distance
- add an accessor method for viewing the goal distance
- add an if statement to the `step` method to recognize the end of the race

what if we wanted to display the dot race visually?

- could utilize the `Circle` class to draw the dots
- unfortunately, `Circle` only has methods for relative movements
we need a `Circle` method for absolute movement (based on a `Dot`'s position)

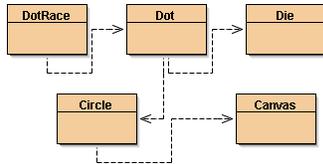
```
/**
 * Move the circle to a specific location on the canvas.
 * @param xpos the new x-coordinate for the circle
 * @param ypos the new y-coordinate for the circle
 */
public void moveTo(int xpos, int ypos) {
    this.erase();
    this.xPosition = xpos;
    this.yPosition = ypos;
    this.draw();
}
```

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Adding graphics

due to our modular design,
changing the display is easy

- each Dot object will maintain and display its own Circle image



- add Circle field
- constructor creates the Circle and sets its color
- showPosition moves the Circle (instead of displaying text)

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;
    private Circle dotImage;

    public Dot(String color, int maxStep) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
        this.dotImage = new Circle();
        this.dotImage.setColor(color);
    }

    public void step() {
        this.dotPosition += this.die.roll();
    }

    public void reset() {
        this.dotPosition = 0;
    }

    public int getPosition() {
        return this.dotPosition;
    }

    public void showPosition() {
        this.dotImage.moveTo(this.dotPosition, 68);
        this.dotImage.setVisible();
    }
}
```

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Graphical display

note: no modifications are necessary in the DotRace class!!!

- this shows the benefit of modularity
- not only is modular code easier to write, it is easier to change/maintain
- can isolate changes/updates to the class/object in question
- to any other interacting classes, the methods look the same

EXERCISE: make these modifications to the Dot class

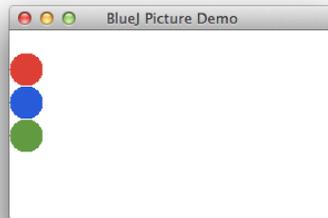
- add Circle field
- create and change color in constructor
- modify showPosition to move and display the circle

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Better graphics

the graphical display is better than text, but still primitive

- dots are drawn on top of each other (same yPositions)
- would be nicer to have the dots aligned vertically (different yPositions)



PROBLEM: each dot maintains its own state & displays itself

- thus, each dot will need to know what yPosition it should have
- but yPosition depends on what order the dots are created in DotRace (e.g., 1st dot has yPosition = 68, 2nd dot has yPosition = 136, ...)
- *how do we create dots with different yPositions?*

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Option 1: Dot parameters

we could alter the Dot class constructor

- takes an additional int that specifies the dot number
- the dotNumber can be used to determine a unique yPosition
- in DotRace, must pass in the number when creating each of the dots

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;
    private Circle dotImage;
    private int dotNumber;

    public Dot(String color, int maxStep, int num) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
        this.dotImage = new Circle();
        this.dotImage.setColor(color);
        this.dotNumber = num;
    }

    . . .

    public void showPosition() {
        this.dotImage.moveTo(this.dotPosition,
                             68*this.dotNumber);
        this.dotImage.setVisible();
    }
}
```

```
public class DotRace {
    private Dot redDot;
    private Dot blueDot;
    private Dot greenDot;

    public DotRace(int maxStep) {
        this.redDot = new Dot("red", maxStep, 1);
        this.blueDot = new Dot("blue", maxStep, 2);
        this.greenDot = new Dot("green", maxStep, 3);
    }

    . . .
}
```

this works, but is inelegant

- why should DotRace have to worry about dot numbers?
- the Dot class should be responsible

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Option 2: a static field

better solution: have each dot keep track of its own number

- this requires a new dot to know how many dots have already been created
- this can be accomplished in Java via a *static field*

```
private static TYPE FIELD = VALUE;
```

- such a declaration creates and initializes a field that is shared by all objects of the class
- when the first object of that class is created, the field is initialized via the assignment
- subsequent objects simply access the existing field

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;
    private Circle dotImage;

    private static int nextAvailable = 1;
    private int dotNumber;

    public Dot(String color, int maxStep) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
        this.dotImage = new Circle();
        this.dotImage.setColor(color);

        this.dotNumber = Dot.nextAvailable;
        Dot.nextAvailable++;
    }

    . . .

    public void showPosition() {
        this.dotImage.moveTo(this.dotPosition,
                             68*this.dotNumber);
        this.dotImage.makeVisible();
    }
}
```

since static fields belong to the class, access as `CLASS.FIELD`

try it! how do static fields appear when you inspect? could die be static?

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Magic numbers

`showPosition` shifts each new dot down 68 pixels in the display

- why 68?

having a "magic number" appear in the code without apparent reason is bad

- unclear to the reader
- difficult to maintain

ideally, could use an accessor method on the `dotImage` to get its diameter

```
dotImage.moveTo(dotPosition, dotImage.getDiameter()*dotNumber);
```

but the `Circle` class does not provide accessor methods! ☹

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;
    private Circle dotImage;

    private static int nextAvailable = 1;
    private int dotNumber;

    public Dot(String color, int maxStep) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
        this.dotImage = new Circle();
        this.dotImage.setColor(color);

        this.dotNumber = Dot.nextAvailable;
        Dot.nextAvailable++;
    }

    . . .

    public void showPosition() {
        this.dotImage.moveTo(this.dotPosition,
                             68*this.dotNumber);
        this.dotImage.makeVisible();
    }
}
```

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Final static

if can't get the diameter from Circle, will need to store in Dot

- store the diameter in a field, can then use to set the circle size (in the constructor) and space dots (in showPosition)
- since all dots will have the same size, make the field *static*
- since the value should not change, can also make it *final*
- once initialized, a final value cannot be changed (any attempt causes a compiler error)

```
public class Dot {
    private Die die;
    private String dotColor;
    private int dotPosition;
    private Circle dotImage;

    private static int nextAvailable = 1;
    private int dotNumber;

    private final static int dotSize = 60;

    public Dot(String color, int maxStep) {
        this.die = new Die(maxStep);
        this.dotColor = color;
        this.dotPosition = 0;
        this.dotImage = new Circle();
        this.dotImage.setColor(color);
        this.dotImage.setSize(Dot.dotSize);

        this.dotNumber = Dot.nextAvailable;
        Dot.nextAvailable++;
    }

    . . .

    public void showPosition() {
        this.dotImage.moveTo(this.dotPosition,
            Dot.dotSize*this.dotNumber);
        this.dotImage.makeVisible();
    }
}
```

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Conditional repetition

running a dot race is a tedious task

- you must call `step` and `showStatus` repeatedly to see each step in the race

a better solution would be to automate the repetition

in Java, a while loop provides for *conditional repetition*

- similar to an if statement, behavior is controlled by a condition (Boolean test)
- as long as the condition is true, the code in the loop is executed over and over

```
while (BOOLEAN_TEST) {
    STATEMENTS TO BE EXECUTED
}
```

```
int num = 1;
while (num < 5) {
    System.out.println(num);
    num++;
}
```

```
int x = 10;
int sum = 0;
while (x > 0) {
    sum += x;
    x -= 2;
}
System.out.println(sum);
```

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runRace method

can define a `DotRace` method with a while loop to run the entire race

in pseudocode:

```
RESET THE DOT POSITIONS
SHOW THE DOTS
while (NO DOT HAS WON) {
    HAVE EACH DOT TAKE A STEP
    SHOW THE DOTS
}
```

```
/**
 * Conducts an entire dot race, showing the status
 * after each step.
 */
public void runRace() {
    this.reset();
    this.showStatus();
    while (this.getRedPosition() < this.goalDistance &&
           this.getBluePosition() < this.goalDistance) {
        this.step();
        this.showStatus();
    }
}
```

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Private methods

once we have `runRace`, we might want to limit low-level interaction

declaring a method to be `private` makes it:

- invisible to the user (e.g., doesn't show up in BlueJ)
- but still usable by other methods (we can refer to it as a *helper method*)

```
public class DotRace {
    private Dot redDot;
    private Dot blueDot;
    private int goalDistance;

    public DotRace(int maxStep, int goal) {
        this.redDot = new Dot("red", maxStep);
        this.blueDot = new Dot("blue", maxStep);
        this.goalDistance = goal;
    }

    public int getGoalDistance() {
        return this.goalDistance;
    }

    public void runRace() {
        this.reset();
        this.showStatus();
        while (this.getRedPosition() < this.goalDistance &&
               this.getBluePosition() < this.goalDistance) {
            this.step();
            this.showStatus();
        }
    }

    ///////////////////////////////////////////////////
    private int getRedPosition() { ... }
    private int getBluePosition() { ... }
    private void step() { ... }
    private void showStatus() { ... }
    private void reset() { ... }
}
```

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Class/object summary

a class defines the content and behavior of a new type

- *fields*: variables that maintain the state of an object of that class
 - fields persist as long as the object exists, accessible to all methods
 - if want a single field to be shared by all objects in a class, declare it to be *static*
 - if it is a constant value that won't change, declare it to be *final static*
 - to store a primitive value: declare a variable and assign it a value
 - to store an object: declare a variable, call a constructor and assign to the variable
- *methods*: collections of statements that implement behaviors
 - methods will usually access and/or update the fields to produce behaviors
 - statements: assignment, println, return, if, if-else, while, method call (internal & external)
 - parameters* are variables that store values passed to a method (allow for generality)
 - parameters persist only while the method executes, accessible only to the method
 - local variables are variables that store temporary values within a method
 - local variables exist from point they are declared to the end of method execution
 - private* methods are invisible to the user, but can be called by other methods in the class
- *constructors*: methods (same name as class) that create and initialize an object
 - a constructor assigns initial values to the fields of the object (can have more than one)

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