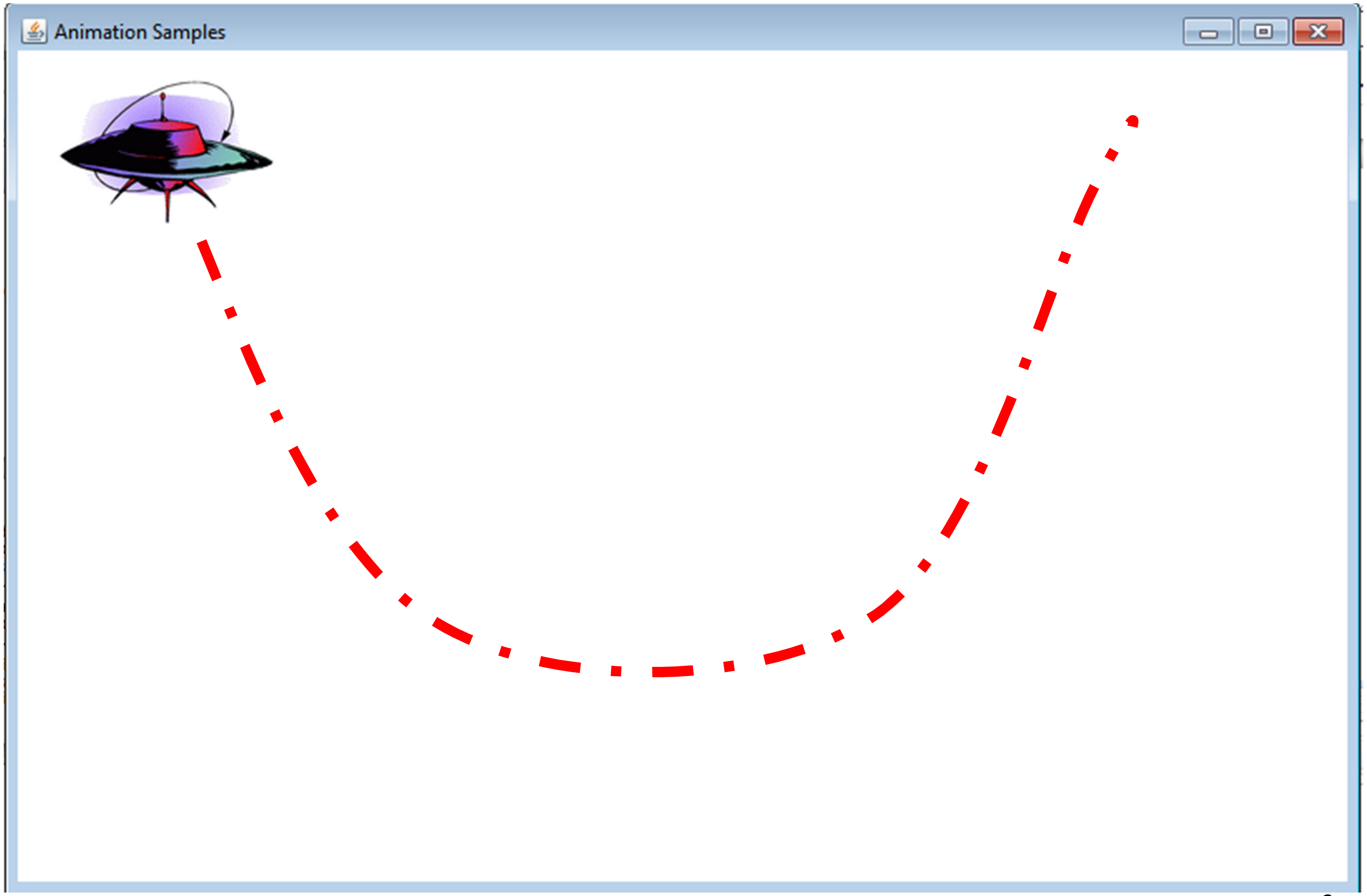
CS324e - Elements of Graphics and Visualization

Intro to Animation

Animation

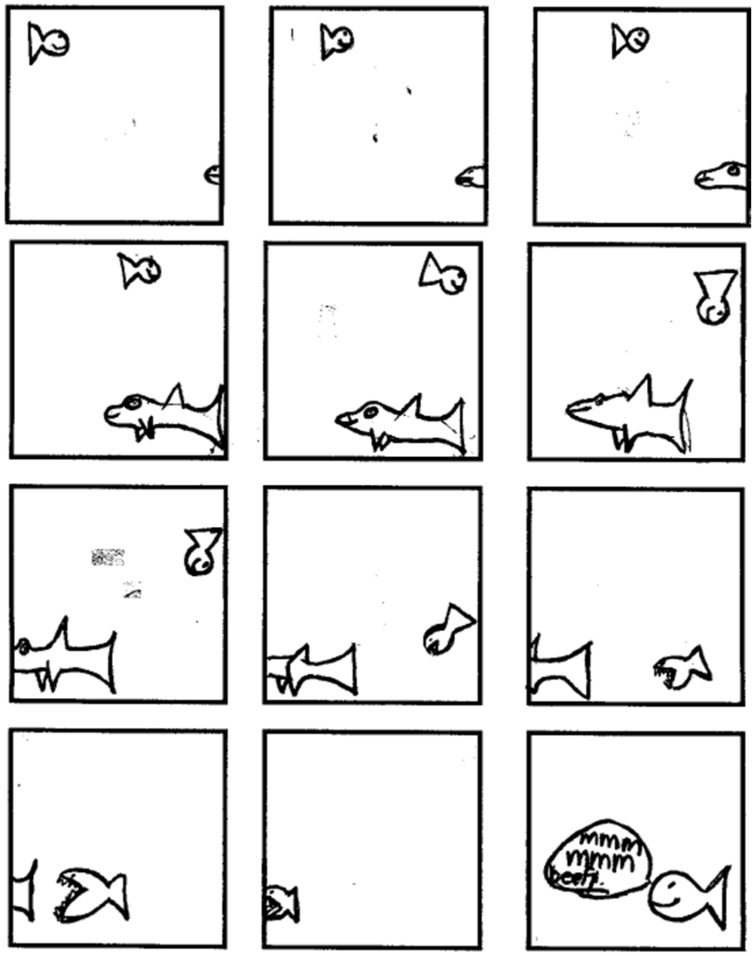
- definition: time-based alteration of graphical objects through different states, locations, sizes, and orientations
  - FRC chapter 12
- alteration: change the way we are drawing objects
  - all the stuff from graphics basics
- time-based: define how objects change *over time* and render objects based on this as time goes by

Make the Ship Move



Frame

- Frame: one still drawing
- illusion of motion achieved by drawing multiple frames with slight differences in how graphical object is rendered
  - a series of still drawings shown quickly
  - like a flip book

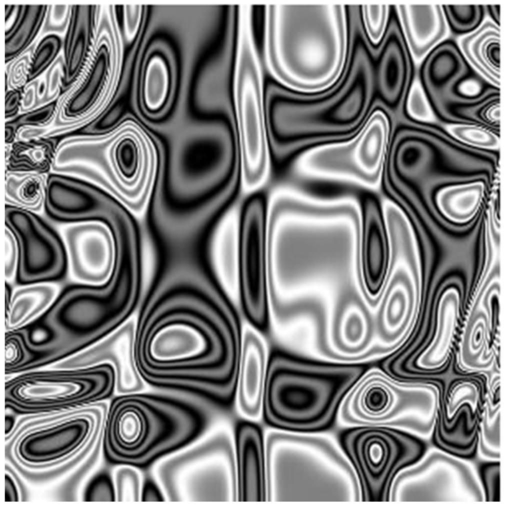


Time-Based vs. Frame-Based

- We will do time based animation
  - amount of movement or alteration based on how much time has passed
- In framed based animation the amount of movement or alteration is defined per frame (instead of per unit time)
- Frame rate: number of frames drawn per unit time, usually per second
- Frame based relies on strictly controlling the frame rate

Controlling Frame Rate

- Difficult based on
  - speed of system (which varies between systems your program will run on)
  - complexity of what is being rendered



Series of Attempts at Animation

- Attempt 1:

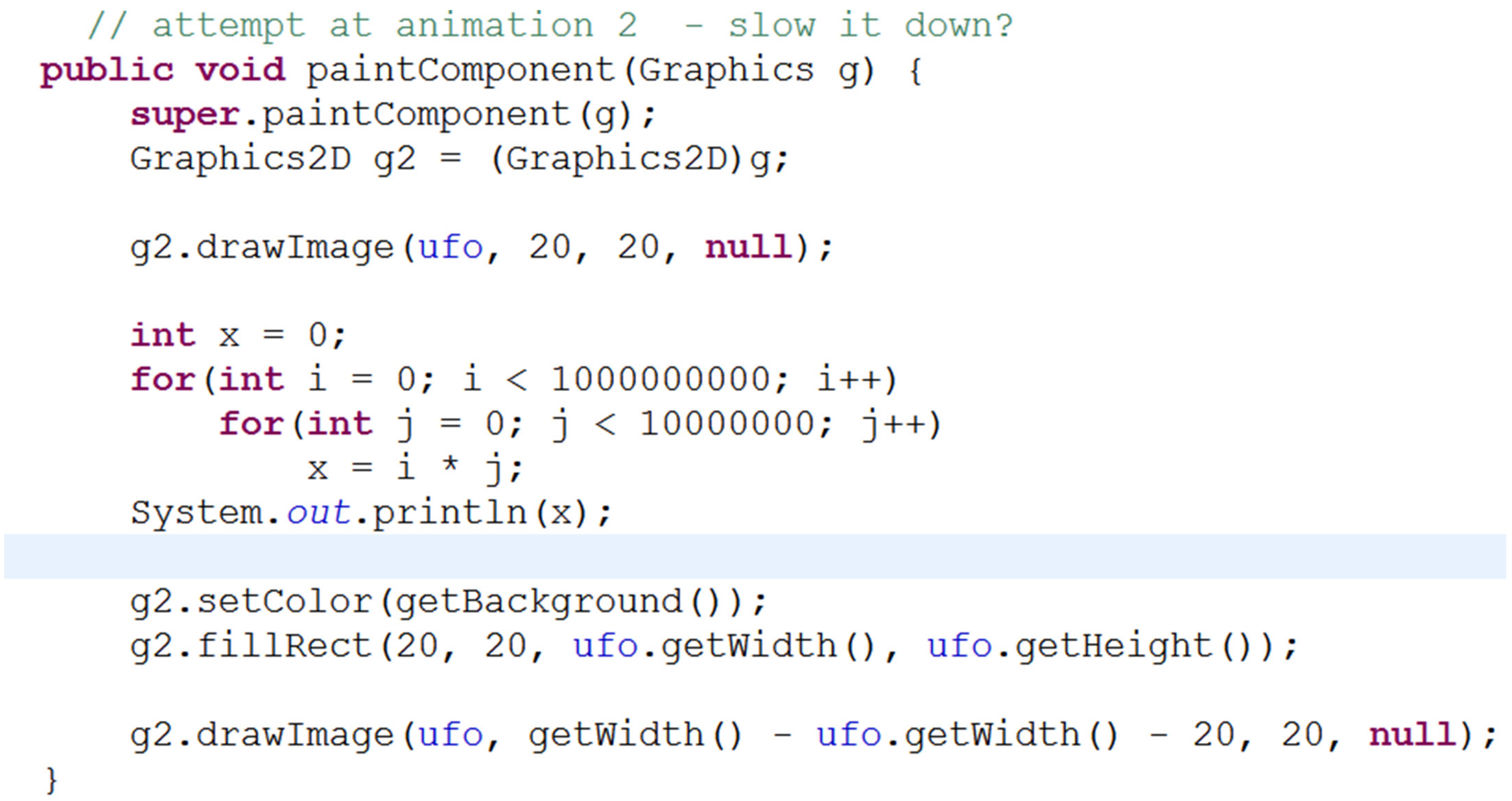
```
public void paintComponent(Graphics g) {
    super.paintComponent(g);
    Graphics2D g2 = (Graphics2D)g;

    g2.drawImage(ufo, 20, 20, null);

    g2.setColor(getBackground());
    g2.fillRect(20, 20, ufo.getWidth(), ufo.getHeight());

    g2.drawImage(ufo, getWidth() - ufo.getWidth() - 20, 20, null);
```

- What is result when run?
- Why?

Problems

- Teleportation != Animation
- Too fast
- Swing Buffering
- Motion not time based

Second Attempt



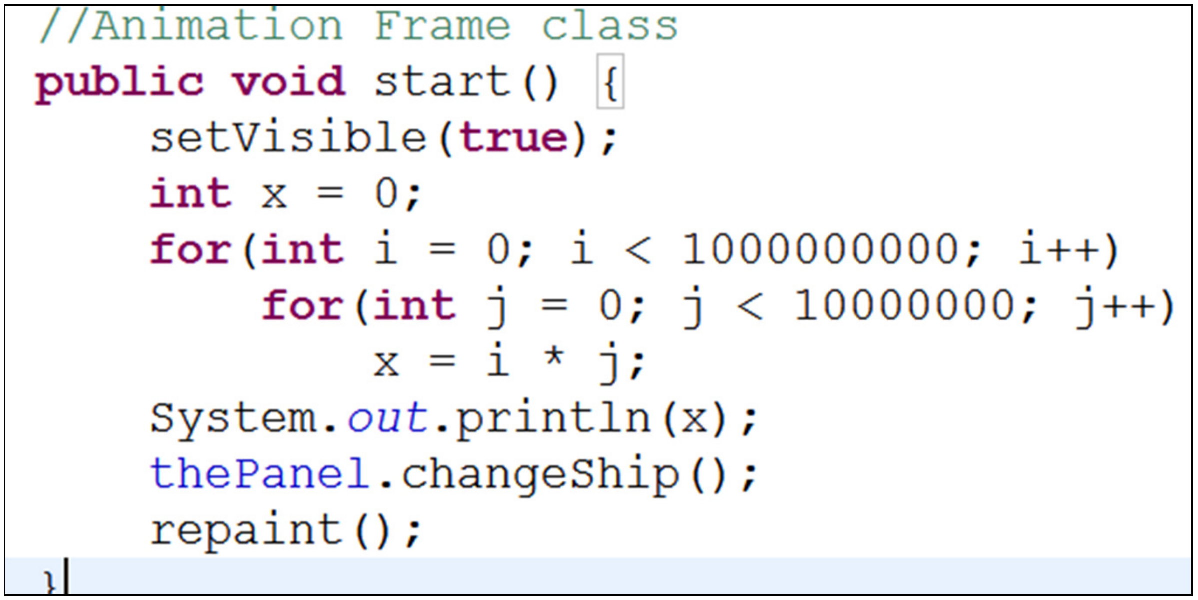
```
  // attempt at animation 2  - slow it down?
public void paintComponent(Graphics g) {
    super.paintComponent(g);
    Graphics2D g2 = (Graphics2D)g;

    g2.drawImage(ufo, 20, 20, null);

    int x = 0;
    for(int i = 0; i < 1000000000; i++)
        for(int j = 0; j < 10000000; j++)
            x = i * j;
    System.out.println(x);

    g2.setColor(getBackground());
    g2.fillRect(20, 20, ufo.getWidth(), ufo.getHeight());

    g2.drawImage(ufo, getWidth() - ufo.getWidth() - 20, 20, null);
}
```

- What is wrong with this attempt?

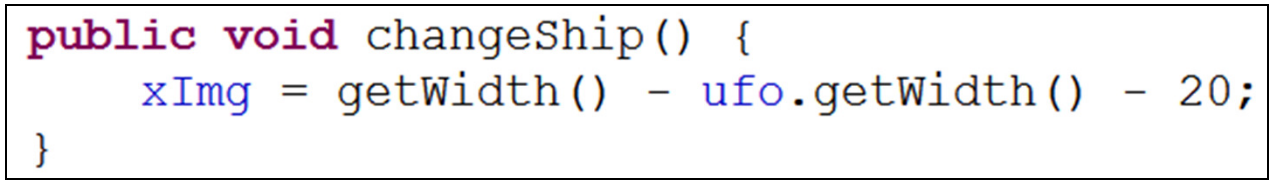
Third Attempt

- Remember, swing uses a back buffer
- All the drawing done to the back buffer (essentially a buffered image) and when it is done the result is displayed
- All drawing from paintComponent appears at once
  - recall the random art assignment
  - didn't see a few pixels at a time did we?

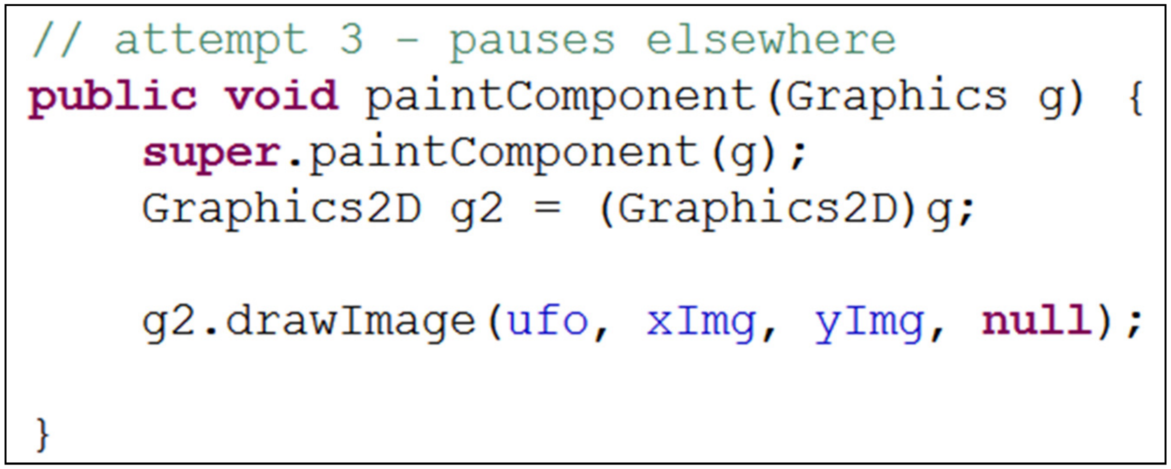
Third Attempt



```java
//Animation Frame class
public void start() {
    setVisible(true);
    int x = 0;
    for(int i = 0; i < 1000000000; i++)
        for(int j = 0; j < 10000000; j++)
            x = i * j;
    System.out.println(x);
    thePanel.changeShip();
    repaint();
}
```



```java
public void changeShip() {
    xImg = getWidth() - ufo.getWidth() - 20;
}
```



```java
// attempt 3 - pauses elsewhere
public void paintComponent(Graphics g) {
    super.paintComponent(g);
    Graphics2D g2 = (Graphics2D)g;

    g2.drawImage(ufo, xImg, yImg, null);

}
```

Teleportation != Animation

- Must change the position of the ship a little bit at a time
- Change the x position of the ship a little bit at a time
- Eventually alter y as well

Fourth Attempt

```
// Animation Panel class
public void moveShip() {
    xImg = yImg = prevXImg = prevYImg = 20;
    int endX = getWidth() - ufo.getWidth() - 20;
    for(int x = xImg; x < endX; x++) {
        repaint();
        // some time passes
        xImg += 1;
    }
}
```

- What happens?

```
// attempt 4 - pauses elsewhere
public void paintComponent(Graphics g) {
    super.paintComponent(g);
    Graphics2D g2 = (Graphics2D)g;

    g2.drawImage(ufo, xImg, yImg, null);

}
```

Too Fast

- Need to allow time to pass between calls to repaint
- Kludge:

```
// Animation Panel class
public void moveShip() {
    xImg = yImg = prevXImg = prevYImg = 20;
    int endX = getWidth() - ufo.getWidth() - 20;
    for(int x = xImg; x < endX; x++) {
        repaint();

        int temp = 0;
        for(int i = 0; i < 10000000; i++)
            for(int j = 0; j < 1000000; j++)
                temp = i * j;
        xImg += 1;
    }
}
```

Movement Achieved

- The ship appears to move, but the approach couldn't be worse
- Must not burn cycles to allow the passage of time
- run on a different machine?
- Also, motion is frame based not time based
  - moving one pixel at a time

Time Based Motion

- define a speed for the object / motion and update x (and y) based on how much time has passed
- $x = x0 + t * (x1 - x0)$
- x current position of ship
- x0 start position of ship
- x1 ending value of ship
- t = fraction of time elapsed, from 0 to 1

Time Based Motion

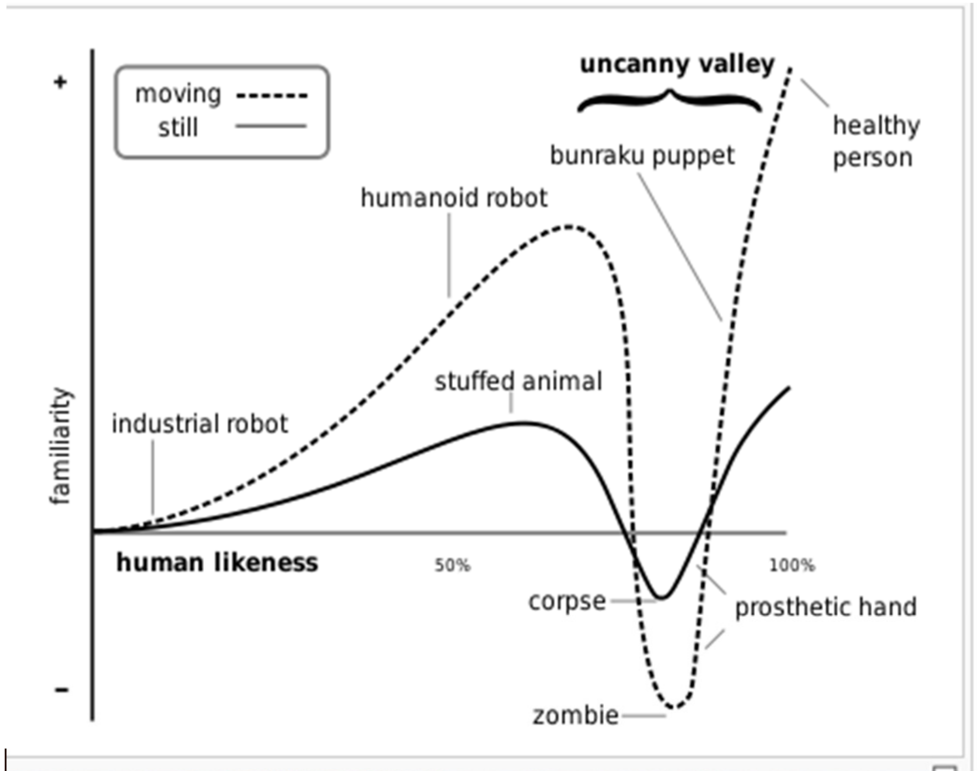
```java
// Animation Panel class
public void moveShip() {
    xImg = yImg = prevXImg = prevYImg = 20;
    int startX = xImg;
    int endX = getWidth() - ufo.getWidth() - 20;
    long animationDuration = 4500; // milliseconds
    long startTime = getTime(); // getTime doesn't exist
    long currentTime = startTime;
    long endTime = startTime + animationDuration;
    while(currentTime < endTime) {
        long elapsedTime = currentTime - startTime;
        float t = ((float) elapsedTime) / animationDuration;
        xImg = (int) (startX + t * (endX - startX));
        repaint();

        // make some time pass

        currentTime = getTime();
    }
}
```

What's The Time

- Two ways of getting system time in Java
  - the time the computer thinks it is
- System.currentTimeMillis()
- System.nanoTime()

Aside - From Last Time

- The uncanny valley
  - Masahiro Mori



System.currentTimeMillis()

- the number of milliseconds (thousandths of a second) that have passed since January 1, 1970
- arbitrary date and time know as the Unix Epoch
- useful for determining how much time has passed between events in the program
- measurements often limited to 10s of milliseconds

System.nanoTime()

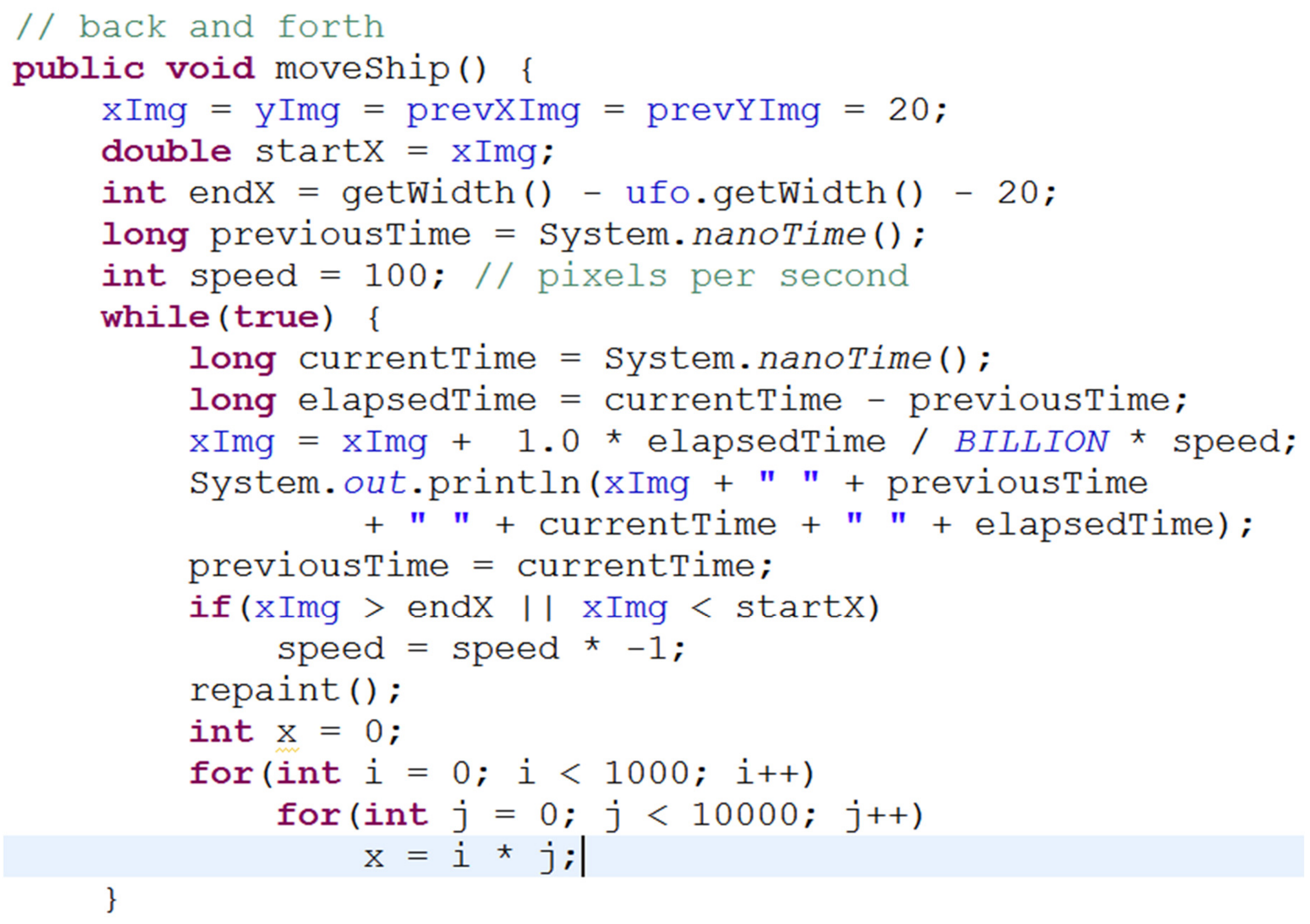
- based on an arbitrary point in time
  - don't assume Unix Epoch
  - may even be in future
- only used for elapsed time
- smaller granularity
  - billionths of a second
- better resolution than System.currentTimeMillis()

Measuring Frame Rate

```
private float getFPS() {
    numFrames++;
    if(startTime == 0) {
        startTime = System.nanoTime();
    }
    else {
        long currentTime = System.nanoTime();
        long delta = (currentTime - startTime);
        // Average the fps every five seconds
        if(delta > FPS_WINDOW) {
            fps = ((float) numFrames) / delta * BILLION;
            numFrames = 0;
            startTime = currentTime;
            System.out.println(fps);
        }
    }
    return fps;
}
```

Move Ship Back and Forth

- x coordinate (xImg) changed to double



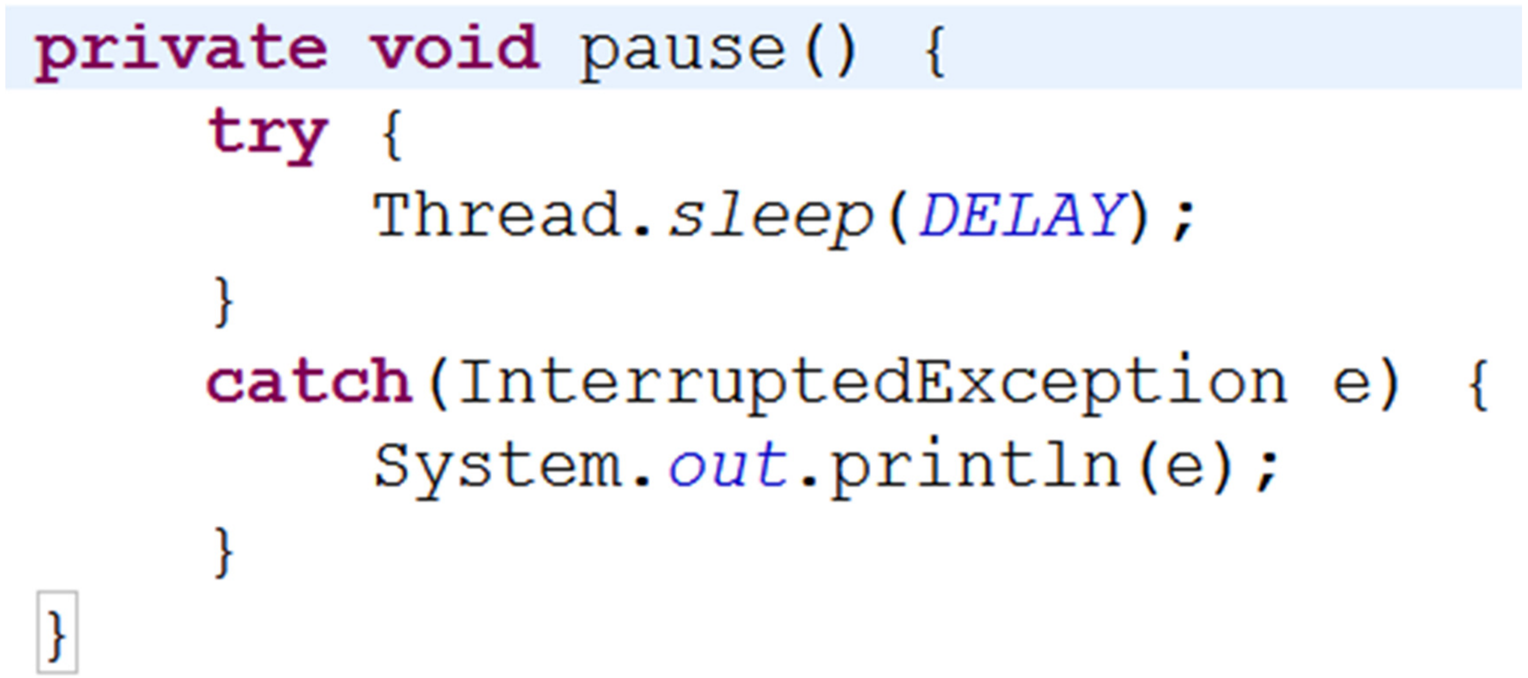
```java
// back and forth
public void moveShip() {
    xImg = yImg = prevXImg = prevYImg = 20;
    double startX = xImg;
    int endX = getWidth() - ufo.getWidth() - 20;
    long previousTime = System.nanoTime();
    int speed = 100; // pixels per second
    while(true) {
        long currentTime = System.nanoTime();
        long elapsedTime = currentTime - previousTime;
        xImg = xImg +  1.0 * elapsedTime / BILLION * speed;
        System.out.println(xImg + " " + previousTime
                + " " + currentTime + " " + elapsedTime);
        previousTime = currentTime;
        if(xImg > endX || xImg < startX)
            speed = speed * -1;
        repaint();
        int x = 0;
        for(int i = 0; i < 1000; i++)
            for(int j = 0; j < 10000; j++)
                x = i * j;
    }
```

Pausing

- The delay loop is a horrible kludge
- First option: pause the thread of execution using Thread.sleep() method
- Thread making call is paused by system
- Doesn't do any work, but doesn't burn CPU cycles either
- argument is milliseconds to sleep

Thread.sleep(int millis)

- call pause method from moveShip
- DELAY set to 30 milliseconds



```
private void pause() {
    try {
        Thread.sleep(DELAY);
    }
    catch(InterruptedException e) {
        System.out.println(e);
    }
}
```

- Compare two versions of pausing

Problems With Sleeping

- Thread.sleep() causes the whole thread (program) to stop
- What if we have a lot of computations to do?
- Imagine the random art program
- what if we wanted to "animate" the drawing of the art by showing a few hundred pixels at a time?
- Does Thread.sleep help?

Timers

- To get repeated notifications that some time has passed without putting the whole thread to sleep
- "Timers allow the program to perform repetitive operations at regular time intervals in a way that allows other work to happen asynchronously."
  - FRC

Timer Classes

- java.util.Timer
  - general purpose timer class
- Creates a separate thread of execution (your program forks)
- schedule TimerTasks with a run() method that is called by the Timer
- fixed delay times (adjusts on fly) or fixed rate times (doesn't adjust

javax.swing.Timer

- Create a time and it will make callbacks
- much like our action listeners for buttons and mouse listeners
- Create a time and then create listeners for when the timer goes off
- javax.swing.Timer specifically for Swing applications / GUIs
  - the callbacks are to the Swing Event Dispatch Thread

Fixed Delay Timing

- Timer will adjust delay times to meet desired wakeup call interval
- Events are coalesced:
  – if it gets to far behind some timing events are simply discarded
  – repaint does the same thing

Comparison of Timers

- SwingTimerDemo creates two swing timers
  - one using fixed delay (default)
  - one using fixed rate (events not coalesced)

Swing Fixed Delay

```
// Run a default fixed-delay timer
timer = new Timer(DELAY, new SwingTimerDemo());
startTime = prevTime = System.currentTimeMillis();
System.out.println("Fixed Delay Times");
timer.start();
```

- results:

```
Fixed Delay Times
Elapsed time = 134
Elapsed time = 270
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
Elapsed time = 100
```

Swing Fixed Rate

```java
// Run a timer with no coalescing to get fixed-rate behavior
timer = new Timer(DELAY, new SwingTimerDemo());
startTime = prevTime = System.currentTimeMillis();
timer.setCoalesce(false);
System.out.println("\nFixed Rate Times");
timer.start();
```

- result

```
Fixed Rate Times
Elapsed time = 0
Elapsed time = 100
Elapsed time = 30
Elapsed time = 200
Elapsed time = 30
Elapsed time = 30
Elapsed time = 30
Elapsed time = 30
Elapsed time = 50
Elapsed time = 30
```

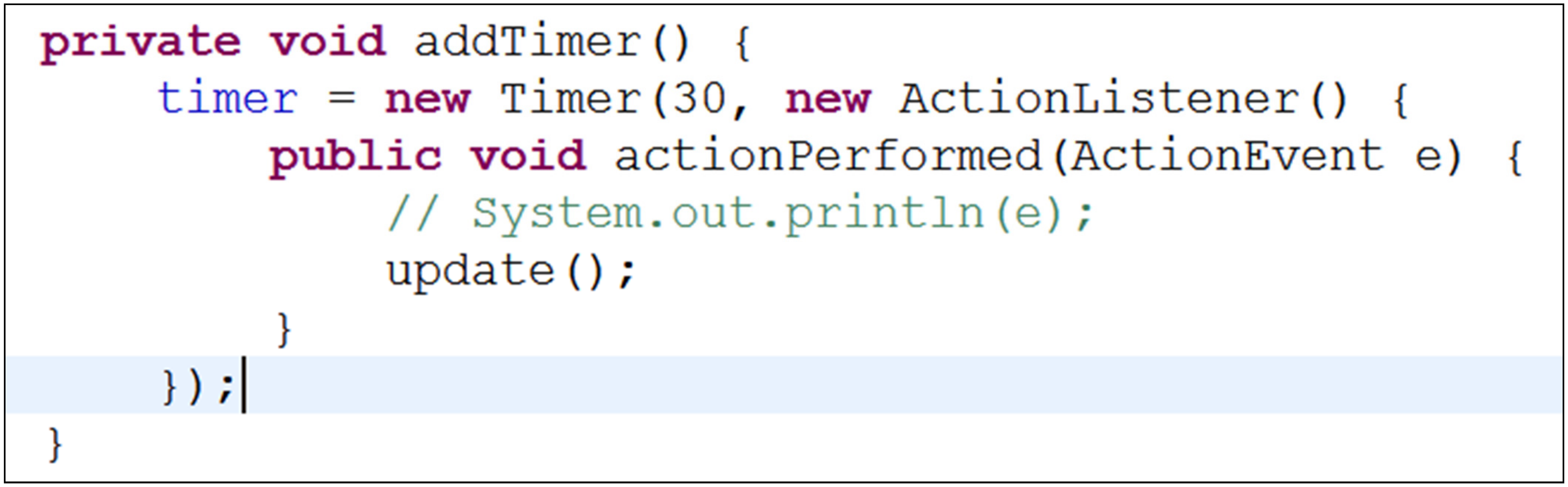
Using Timer in UFO Program

- Loop no longer in moveShip
- constructor for AnimationPanel

```
public AnimationPanel() {
    this.setPreferredSize(new Dimension(WIDTH, HEIGHT));
    loadImage();
    setBackground(Color.WHITE);
    xImg = startX = 20;
    yImg = 20;
    endX = 800 - ufo.getWidth() - 20;
    System.out.println(startX + " " + endX);
    addTimer();
}
```

AnimationPanel With Timer

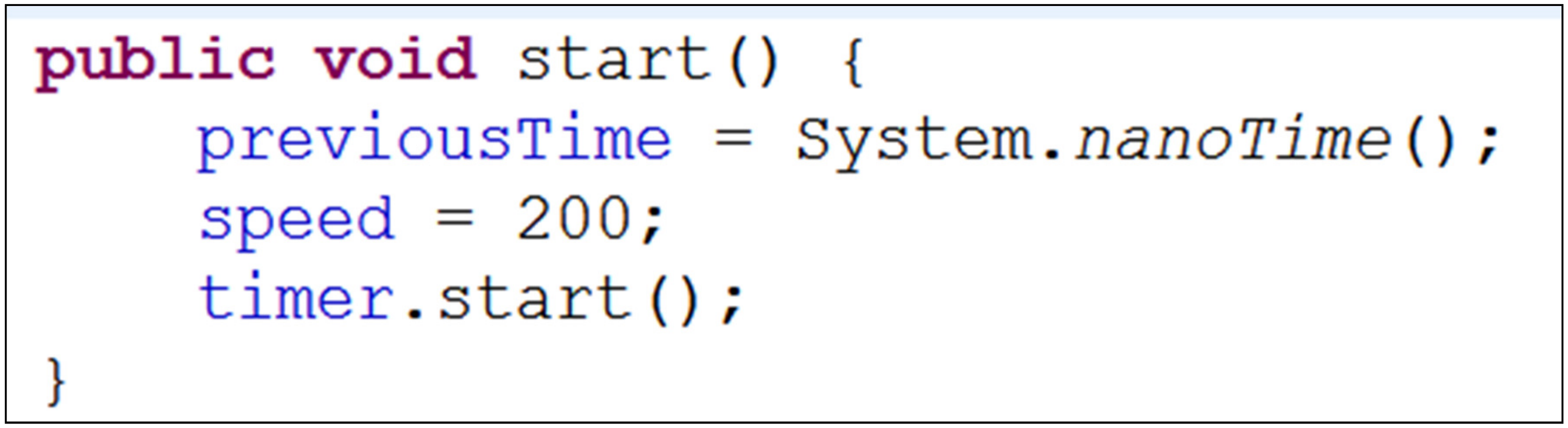
- Create timer
- ActionListener is an annoynomoyus inner class that calls update method on the panel



```
private void addTimer() {
    timer = new Timer(30, new ActionListener() {
        public void actionPerformed(ActionEvent e) {
            // System.out.println(e);
            update();
        }
    });
}
```

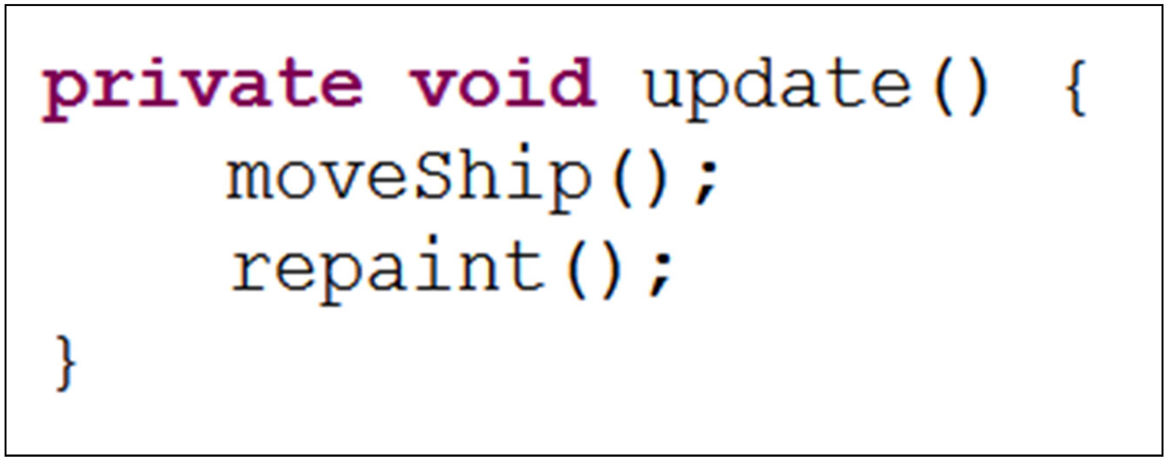
AnimationPanel With Timer

- start method to begin animation



```
public void start() {
    previousTime = System.nanoTime();
    speed = 200;
    timer.start();
}
```

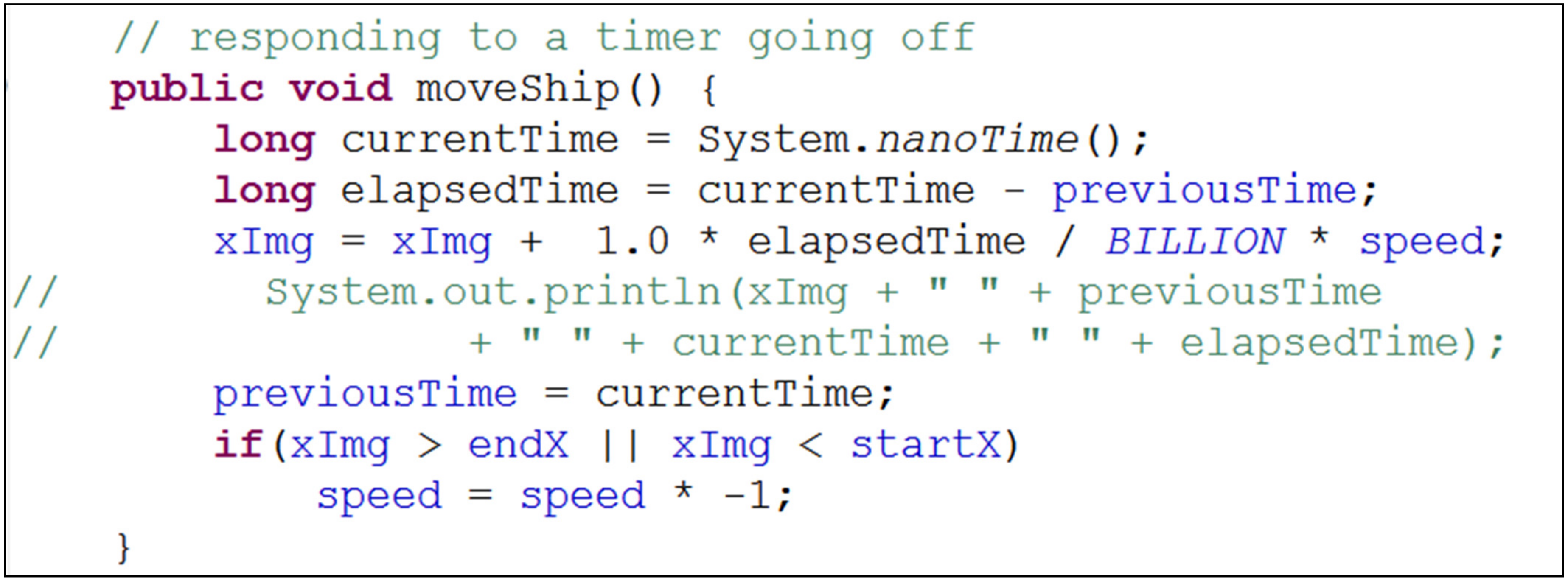
- update method called when timer goes off



```
private void update() {
    moveShip();
    repaint();
}
```

AnimationPanel With Timer

- moveShip
- no loop
- must make many variables instance variables - (what happens if speed local?)



```
    // responding to a timer going off
    public void moveShip() {
        long currentTime = System.nanoTime();
        long elapsedTime = currentTime - previousTime;
        xImg = xImg +  1.0 * elapsedTime / BILLION * speed;
//          System.out.println(xImg + " " + previousTime
//                  + " " + currentTime + " " + elapsedTime);
        previousTime = currentTime;
        if(xImg > endX || xImg < startX)
            speed = speed * -1;
    }
```

What's Next?

- Clearly the logic for the ship does not belong in the AnimationPanel class
- Create a Ship class that contains logic for moving ship
- Move ship in something other than a straight line
- animate ship in another way (shrink, fade out)