
CSE 331

Software Design & Implementation

Fall 2020

Section 3 – HW4, Abstract Data Types, and JUnit

Agenda

- Overview of HW4
- Quick review of polynomial arithmetic
- Review abstract data types (ADTs) by example
- Unit testing with Junit – an initial tour for HW4

HW4 – Polynomial calculator

A homework in 6 parts:

0. Pseudocode algorithms for polynomial arithmetic
1. Conceptual questions about `RatNum`
2. Implement `RatTerm`
3. Implement `RatPoly`
4. Implement `RatPolyStack`
5. Try out your finished calculator!
6. Run your code against our tests to make sure it works!



The RatThings

- **RatNum** ADT
 - A rational number
 - Also includes a NaN (“not a number”) value
- **RatTerm** ADT
 - A polynomial term (rational coefficient w/ integer degree)
- **RatPoly** ADT
 - A polynomial expression (sum of polynomial terms)
- **RatPolyStack** ADT
 - An ordered collection of polynomial expressions



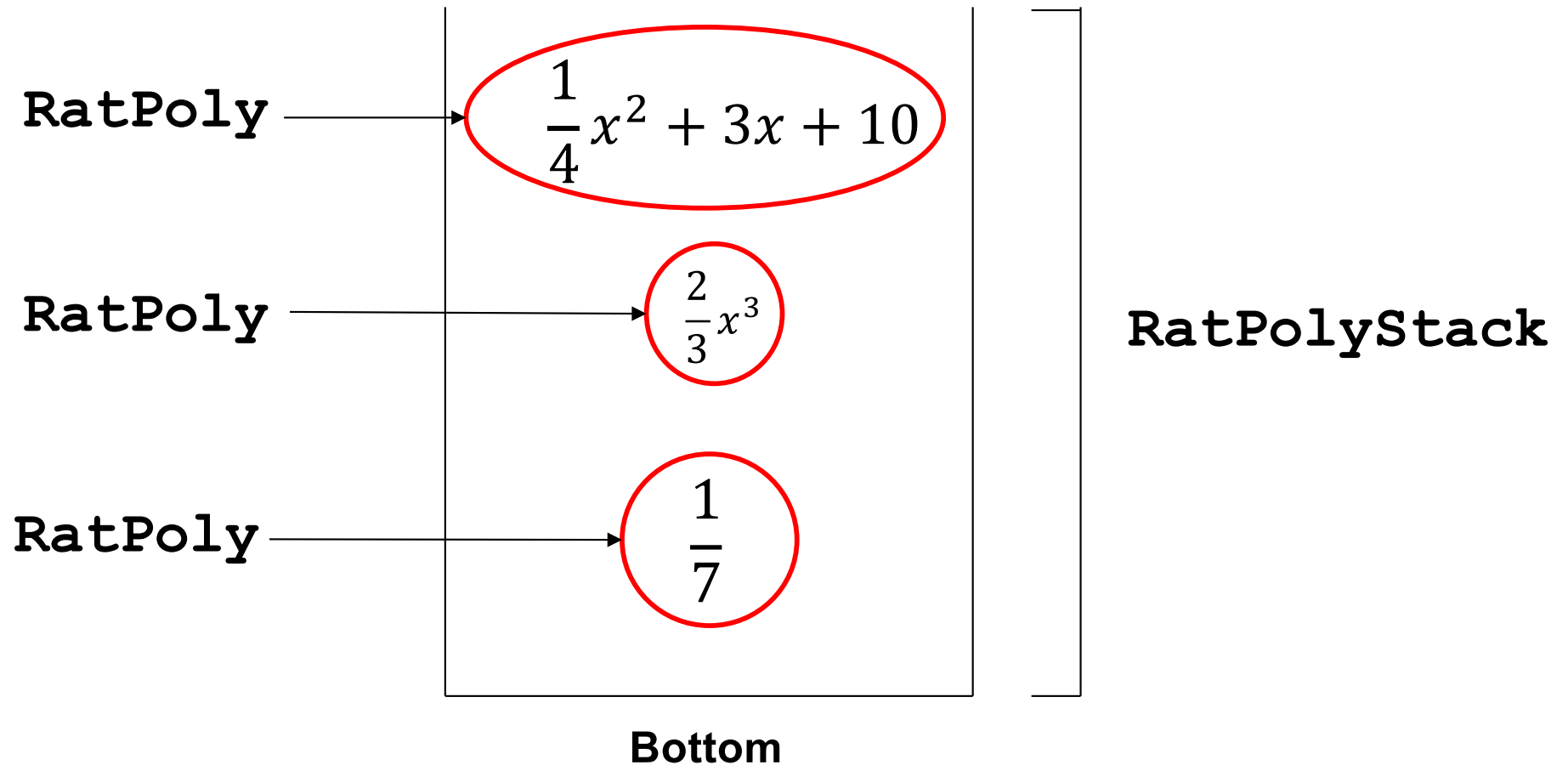
The RatThings

RatPoly → $\frac{1}{4}x^2 + 3x + 10$

RatTerm → $\frac{2}{3}x^3$

RatNum → $\frac{1}{7}$

The RatThings



Polynomial arithmetic

Review arithmetic operations over polynomial expressions:

1. Addition
2. Subtraction
3. Multiplication
4. Division

Polynomial addition

$$(5x^4 + 4x^3 - x^2 + 5) + (3x^5 - 2x^3 + x - 5)$$

Polynomial addition

$$(5x^4 + 4x^3 - x^2 + 5) + (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 5x^4 + 4x^3 - 1x^2 + 5 \\ + 3x^5 - 2x^3 + 1x - 5 \\ \hline \end{array}$$

Polynomial addition

$$(5x^4 + 4x^3 - x^2 + 5) + (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 0x^5 \quad 5x^4 + \quad 4x^3 + \quad - 1x^2 \quad + 0x \quad + 5 \\ + \quad 3x^5 + 0x^4 \quad - 2x^3 \quad + 0x^2 \quad + 1x \quad - 5 \\ \hline \end{array}$$

Polynomial addition

$$(5x^4 + 4x^3 - x^2 + 5) + (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 0x^5 + 5x^4 + 4x^3 - 1x^2 + 0x + 5 \\ + 3x^5 + 0x^4 - 2x^3 + 0x^2 + 1x - 5 \\ \hline 3x^5 + 5x^4 + 2x^3 - 1x^2 + 1x + 0 \end{array}$$

Polynomial subtraction

$$(5x^4 + 4x^3 - x^2 + 5) - (3x^5 - 2x^3 + x - 5)$$

Polynomial subtraction

$$(5x^4 + 4x^3 - x^2 + 5) - (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 5x^4 + 4x^3 - 1x^2 + 5 \\ - 3x^5 - 2x^3 + 1x - 5 \\ \hline \end{array}$$

Polynomial subtraction

$$(5x^4 + 4x^3 - x^2 + 5) - (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 0x^5 + 5x^4 + 4x^3 - 1x^2 + 0x + 5 \\ - 3x^5 + 0x^4 - 2x^3 + 0x^2 + 1x - 5 \\ \hline \end{array}$$

Polynomial subtraction

$$(5x^4 + 4x^3 - x^2 + 5) - (3x^5 - 2x^3 + x - 5)$$

$$\begin{array}{r} 0x^5 + 5x^4 + 4x^3 - 1x^2 + 0x + 5 \\ - 3x^5 + 0x^4 - 2x^3 + 0x^2 + 1x - 5 \\ \hline -3x^5 + 5x^4 + 6x^3 - 1x^2 - 1x + 10 \end{array}$$

Polynomial multiplication

$$(4x^3 - x^2 + 5) \times (x - 5)$$

Polynomial multiplication

$$(4x^3 - x^2 + 5) \times (x - 5)$$

$$\begin{array}{r} 4x^3 - x^2 + 5 \\ \times \\ \hline 1x - 5 \end{array}$$

Polynomial multiplication

$$(4x^3 - x^2 + 5) \times (x - 5)$$

$$\begin{array}{r} - \\ \times \\ \hline - \\ -20x^3 + 5x^2 \\ - 25 \end{array}$$

Polynomial multiplication

$$(4x^3 - x^2 + 5) \times (x - 5)$$

$$\begin{array}{r}
 \\
 \\
 \times \\
 \hline
 \\
 \\
 4x^4 - 1x^3 + 5x - 25
 \end{array}$$

The image shows a handwritten-style polynomial multiplication. The multiplicand $4x^3 - x^2 + 5$ is written in red. The multiplier $x - 5$ is written in blue. A horizontal line separates the two. Below the line, the products are shown in grey: $-20x^3 + 5x^2$ (from $x \times (-x^2 + 5)$) and $4x^4 - 1x^3$ (from $x^3 \times (x - 5)$). The final result $4x^4 - 1x^3 + 5x - 25$ is shown at the bottom. The term $1x$ in the multiplier is circled in green.

Polynomial multiplication

$$(4x^3 - x^2 + 5) \times (x - 5)$$

		$4x^3$	$-$	$1x^2$			$+$	5	
\times						$1x$	$-$	5	
						<hr/>			
			$-$	$20x^3$	$+$	$5x^2$		$-$	25
$+$	$4x^4$	$-$	$1x^3$			$+$	$5x$		
	<hr/>								
	$4x^4$	$-$	$21x^3$	$+$	$5x^2$	$+$	$5x$	$-$	25

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r|l} 1x^3 & 5x^6 \\ -2x & +4x^4 \\ -5 & -1x^3 \\ \hline & +5 \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r|l} 1x^3 + 0x^2 - 2x - 5 & 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5 \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r} 5x^3 \\ 1x^3 + 0x^2 - 2x - 5 \overline{) 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5} \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r} 5x^3 \\ 1x^3 + 0x^2 - 2x - 5 \overline{) 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5} \\ \underline{5x^6 + 0x^5 - 10x^4 - 25x^3} \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r} 5x^3 \\ 1x^3 + 0x^2 - 2x - 5 \overline{) 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5} \\ - 5x^6 + 0x^5 - 10x^4 - 25x^3 \\ \hline 0x^6 + 0x^5 + 14x^4 + 24x^3 \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r} 5x^3 \\ 1x^3 + 0x^2 - 2x - 5 \overline{) 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5} \\ - \quad 5x^6 + 0x^5 - 10x^4 - 25x^3 \\ \hline 0x^6 + 0x^5 + 14x^4 + 24x^3 \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$1x^3 + 0x^2 - 2x - 5$	$5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5$
$-$	$5x^6 + 0x^5 - 10x^4 - 25x^3$
	$0x^6 + 0x^5 + 14x^4 + 24x^3 + 0x^2$

$5x^3$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$\begin{array}{r}
 \\
 1x^3 + 0x^2 - 2x - 5 \overline{) 5x^6 + 0x^5 + 4x^4 - 1x^3 + 0x^2 + 0x + 5} \\
 \underline{- 5x^6 + 0x^5 - 10x^4 - 25x^3} \\
 0x^6 + 0x^5 + 14x^4 + 24x^3 + 0x^2
 \end{array}$$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$					
$1x^3$	$+0x^2$	$-2x$	-5	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
			-	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$			
				$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$	

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$		
$1x^3 + 0x^2 - 2x - 5$	-	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
		-	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$		
		$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$	

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$		
$1x^3 + 0x^2 - 2x - 5$	-	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
		-	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$		
		$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$	
				$14x^4$	$+0x^3$	$-28x^2$	$-70x$	

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$		
$1x^3 + 0x^2 - 2x - 5$	-	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
		-	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$		
			$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$
				-	$14x^4$	$+0x^3$	$-28x^2$	$-70x$
					$0x^4$	$+24x^3$	$+28x^2$	$+70x$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$	
$1x^3 + 0x^2 - 2x - 5$	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
	$-$	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$		
		$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$
			$-$	$14x^4$	$+0x^3$	$-28x^2$	$-70x$
				$0x^4$	$+24x^3$	$+28x^2$	$+70x$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$	
$1x^3 + 0x^2 - 2x - 5$	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
	$- 5x^6$	$+0x^5$	$-10x^4$	$-25x^3$			
	$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$	
			$- 14x^4$	$+0x^3$	$-28x^2$	$-70x$	
			$0x^4$	$+24x^3$	$+28x^2$	$+70x$	$+5$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				$5x^3$	$+0x^2$	$+14x$	$+24$
$1x^3 + 0x^2 - 2x - 5$	5x ⁶	+0x ⁵	+4x ⁴	-1x ³	+0x ²	+0x	+5
	-	5x ⁶	+0x ⁵	-10x ⁴	-25x ³		
		0x ⁶	+0x ⁵	+14x ⁴	+24x ³	+0x ²	+0x
			-	14x ⁴	+0x ³	-28x ²	-70x
				0x ⁴	$+24x^3$	$+28x^2$	$+70x$
					$+5$		

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$1x^3 + 0x^2 - 2x - 5$	$5x^6$	$+0x^5$	$+4x^4$	$-1x^3$	$+0x^2$	$+0x$	$+5$
-	$5x^6$	$+0x^5$	$-10x^4$	$-25x^3$			
	$0x^6$	$+0x^5$	$+14x^4$	$+24x^3$	$+0x^2$	$+0x$	
		-	$14x^4$	$+0x^3$	$-28x^2$	$-70x$	
				$0x^4$	$+24x^3$	$+28x^2$	$+70x$
					$24x^3$	$+0x^2$	$-48x$
							-120
							$+5$

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

				5x³	+0x²	+14x	+24
1x³ + 0x² - 2x - 5	5x ⁶	+0x ⁵	+4x ⁴	-1x ³	+0x ²	+0x	+5
	-	5x ⁶	+0x ⁵	-10x ⁴	-25x ³		
		0x ⁶	+0x ⁵	+14x ⁴	+24x ³	+0x ²	+0x
			-	14x ⁴	+0x ³	-28x ²	-70x
				0x ⁴	+24x ³	+28x ²	+70x
					-	24x ³	+0x ²
							-48x
							-120
							0x³ + 28x² + 118x + 125

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

					quotient	
				5x ³	+0x ²	+14x
				+24		
1x ³ + 0x ² - 2x - 5	5x ⁶	+0x ⁵	+4x ⁴	-1x ³	+0x ²	+0x
	- 5x ⁶	+0x ⁵	-10x ⁴	-25x ³		
	0x ⁶	+0x ⁵	+14x ⁴	+24x ³	+0x ²	+0x
			- 14x ⁴	+0x ³	-28x ²	-70x
			0x ⁴	+24x ³	+28x ²	+70x
				- 24x ³	+0x ²	-48x
				0x ³	+28x ²	+118x
						+125

remainder

Polynomial division

$$(5x^6 + 4x^4 - x^3 + 5) / (x^3 - 2x - 5)$$

$$5x^3 + 14x + 24 + \frac{28x^2 + 118x + 125}{x^3 - 2x - 5}$$

Abstract data types by example

Review ADT concepts through two examples:

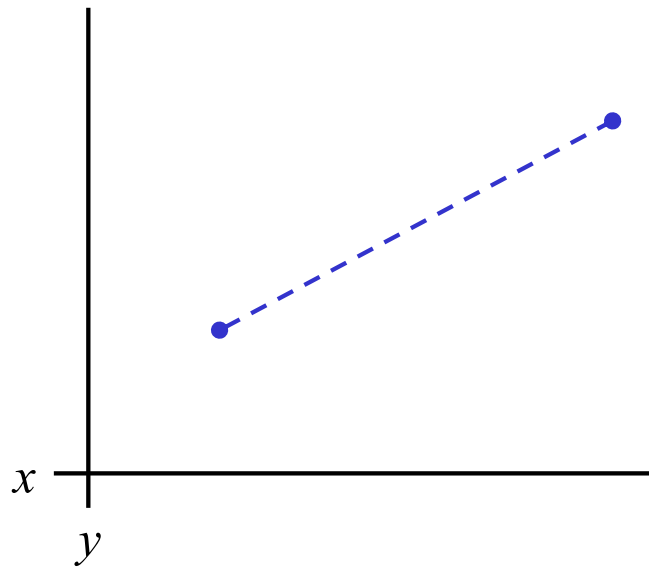
- A **Line** ADT
- A **Rectangle** ADT

On the course website, see “Resources” → “Class and Method Specifications” for a handy guide with full details.

We won't cover representation invariants today (see Friday's lecture).

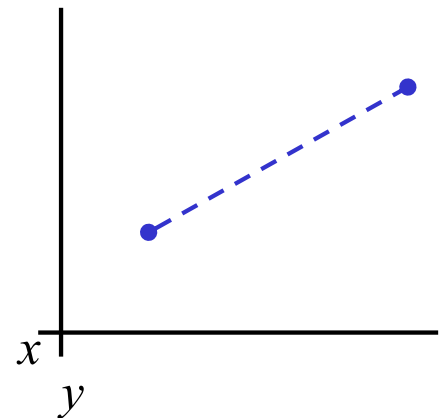
Line ADT

Concept: A line segment in the Cartesian co-ordinate plane



Line ADT: Representation #1

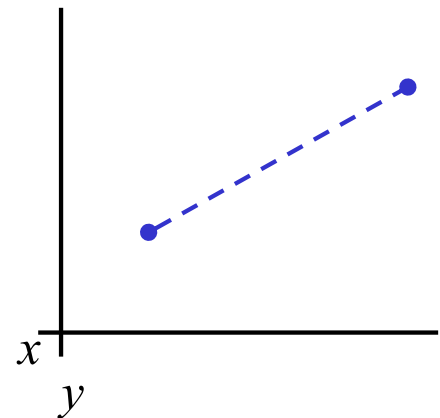
```
/**
 * A Line is a mutable 2D line segment with endpoints
 * p1 and p2.
 */
public class Line {
    // Abstract state is line with endpoints p1 and p2
    private Point p1, p2;
}
```



Line ADT: Representation #2

```
/**
 * A Line is a mutable 2D line segment with endpoints
 * p1 and p2.
 */
public class Line {
    // Abstract state is line with endpoints (x1, y1) and
    //                                     (x2, y2)
    private int x1, x2;
    private int y1, y2;
}
```

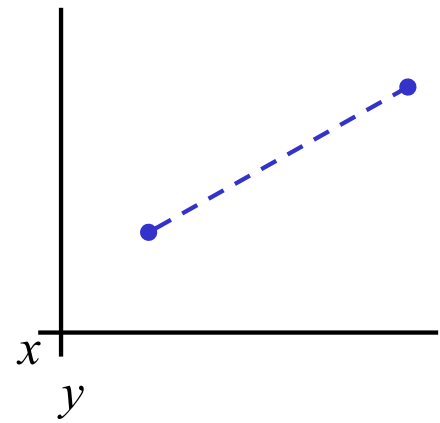
Does this representation have any advantages over #1?



Line ADT: Representation #3

```
/**
 * A Line is a mutable 2D line segment with endpoints
 * p1 and p2.
 */
public class Line {
    // Abstract state is line with endpoints (x1, y1) and
    // (x1 + len * cos(angle), y1 + len * sin(angle))
    private int x1, y1;
    private double angle;
    private double len;
}
```

Does this representation have any advantages over #1?



Try it yourself!

Write your own specification of a Rectangle ADT on the handout.

Then give two different possible representations for your Rectangle ADT and write abstraction functions for them

Testing: A quick introduction

- For HW 4, you'll be running our test suite to verify your RatThings work.
- Let's do a quick walkthrough of our test suite
 - Just know how it works; don't need to know how to write tests!

JUnit

- Industry-standard Java toolkit for unit testing
 - We're using JUnit 4
- A unit test is a test for one “component” by itself
 - “Component” typically a class or a method
- Each unit test written as a method
 - We'll see the particulars in a moment...
- Closely related unit tests should be grouped into a class
 - For example, all unit tests for the same ADT implementation

Writing tests with JUnit

Annotate a method with `@Test` to flag it as a JUnit test

```
import org.junit.*;
import static org.junit.Assert.*;

/** Unit tests for my Foo ADT implementation */
public class FooTests {
    @Test
    public void testBar() {
        ... /* use JUnit assertions in here */
    }
}
```

Using JUnit assertions

- JUnit assertions establish success or failure of the test method
 - *Note: JUnit assertions are different from Java's **assert** statement*
- Use to check that an actual result matches the expected value
 - Example: `assertEquals(42, meaningOfLife());`
 - Example: `assertTrue(list.isEmpty());`
- A test method stops immediately after the first assertion failure
 - If no assertion fails, then the test method passes
 - Other test methods still run either way
- JUnit results show details of any test failures

Common JUnit assertions

JUnit's documentation has a full list, but these are the most common assertions.

Assertion	Failure condition
<code>assertTrue(<i>test</i>)</code>	<code><i>test</i> == false</code>
<code>assertFalse(<i>test</i>)</code>	<code><i>test</i> == true</code>
<code>assertEquals(<i>expected</i>, <i>actual</i>)</code>	<code><i>expected</i> and <i>actual</i> are not equal</code>
<code>assertSame(<i>expected</i>, <i>actual</i>)</code>	<code><i>expected</i> != <i>actual</i></code>
<code>assertNotSame(<i>expected</i>, <i>actual</i>)</code>	<code><i>expected</i> == <i>actual</i></code>
<code>assertNotNull(<i>value</i>)</code>	<code><i>value</i> != null</code>
<code>assertNotNull(<i>value</i>)</code>	<code><i>value</i> == null</code>

Any JUnit assertion can also take a string to show in case of failure, e.g., `assertEquals("helpful message", expected, actual)`.

Checking for a thrown exception

- Should test that your code throws exceptions as specified
- This kind of test method fails if its body does *not* throw an exception of the named class
 - May not need any JUnit assertions inside the test method unlike our previous guideline

```
@Test(expected=IndexOutOfBoundsException.class)
public void testGetEmptyList() {
    List<String> list = new ArrayList<String>();
    list.get(0);
}
```

Test ordering, setup, clean-up

JUnit does not promise to run tests in any particular order.

However, JUnit can run helper methods for common setup/cleanup

- Run before/after *each* test method in the class:

```
@Before
```

```
public void m() { ... }
```

```
@After
```

```
public void m() { ... }
```

- Run once before/after running *all* test methods in the class:

```
@BeforeClass
```

```
public static void m() { ... }
```

```
@AfterClass
```

```
public static void m() { ... }
```