Warmup

A programmer's roommate tells him, "Would you mind going to the store and picking up a loaf of bread. Also, if they have eggs, get a dozen."

The programmer returns with 12 loaves of bread.

Section 3:
HW4, ADTs, and more

WITH MATERIAL FROM VINOD RATHNAM, ALEX MARIAKAKIS, KRYSTA YOUSOUFIAN, MIKE ERNST, KELLEN DONOHUE

Agenda

Polynomial arithmetic

Abstract data types (ADT)

Representation invariants (RI)

Abstraction Functions

HW4: Polynomial Graphing Calculator

Problem 0: Write pseudocode algorithms for polynomial operations

Problem 1: Answer questions about RatNum

Problem 2: Implement RatTerm

Problem 3: Implement RatPoly

Problem 4: Implement RatPolyStack

Problem 5: Try out the calculator

RatThings

RatNum
- ADT for a Rational Number
- Has NaN

RatTerm
- Single polynomial term
- Coefficient (RatNum) & degree

RatPoly
- Sum of RatTerms

RatPolyStack
- Ordered collection of RatPolys

Polynomial Addition

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

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$$\begin{array}{rrrrrr} & 5x^4 & + 4x^3 & - x^2 & & + 5 \\ + & 3x^5 & - 2x^3 & & + x & - 5 \end{array}$$

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

$$\begin{array}{rrrrrrr} & 5x^4 & + 4x^3 & - x^2 & 0x & + 5 \\ + & 3x^5 & 0x^4 & - 2x^3 & 0x^2 + x & - 5 \end{array}$$

Polynomial Addition

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

$$\begin{array}{rrrrrrr}
 & 5x^4 & + 4x^3 & - x^2 & 0x & & + 5 \\
+ \quad 3x^5 & 0x^4 & - 2x^3 & 0x^2 & + x & & - 5 \\
\hline
\mathbf{3x^5} & \mathbf{+ 5x^4} & \mathbf{+ 2x^3} & \mathbf{- x^2} & \mathbf{+ x} & & \mathbf{+ 0}
\end{array}$$

Polynomial Subtraction

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

$$\begin{array}{rrrrrr} & 5x^4 & + 4x^3 & - x^2 & & + 5 \\ - & 3x^5 & - 2x^3 & & + x & - 5 \end{array}$$

Polynomial Subtraction

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

$$\begin{array}{rrrrrrr} & 5x^4 & + 4x^3 & - x^2 & 0x & & + 5 \\ - & 3x^5 & 0x^4 & - 2x^3 & 0x^2 & + x & - 5 \end{array}$$

Polynomial Subtraction

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

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

Polynomial Multiplication

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

Polynomial Multiplication

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

$$
\begin{array}{rr}
 & 4x^3 - x^2 + 5 \\
* & x - 5 \\
\hline
\end{array}
$$

Polynomial Multiplication

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

$$
\begin{array}{rrrrr}
 & 4x^3 & -\ x^2 & +\ 5 & \\
* & & x & -\ 5 & \\
\hline
 & -20x^3 & +\ 5x^2 & -\ 25 &
\end{array}
$$

Polynomial Multiplication

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

$$
\begin{array}{rrrrr}
 & & 4x^3 & -\ x^2 & +\ 5 \\
* & & & x & -\ 5 \\
\hline
 & -20x^3 & +\ 5x^2 & & -\ 25 \\
4x^4 & -x^3 & & +\ 5x &
\end{array}
$$

Polynomial Multiplication

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

$$\begin{array}{rrrrrr}
 & & & 4x^3 & -\ x^2 & +\ 5 \\
* & & & & x & -\ 5 \\
\hline
 & & -20x^3 & +\ 5x^2 & & -\ 25 \\
+ & 4x^4 & -x^3 & & +\ 5x & \\
\hline
 & \mathbf{4x^4} & \mathbf{-21x^3} & \mathbf{+\ 5x^2} & \mathbf{+\ 5x} & \mathbf{-\ 25}
\end{array}$$

Poly Division

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

Poly Division

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

$x^3 - 2x - 5 \overline{\big)\, 5x^6 + 4x^4 - x^3 + 5}$

Poly Division

1	0	-2	-5	5	0	4	-1	0	0	5

Poly Division

5

1 0 -2 -5 | 5 0 4 -1 0 0 5

Poly Division

5

1 0 -2 -5 | 5 0 4 -1 0 0 5

5 0-10 -25

Poly Division

5

1	0	-2	-5	5	0	4	-1	0	0	5
				5	0	-10	-25			
				0	0	14	24			

Poly Division

```
                    5
1  0 -2 -5 | 5  0  4  -1  0  0  5
          | 5  0-10 -25
          |-----------------------
          | 0  0 14  24
          |      14  24 0
```

Poly Division

```
                          5   0
1   0  -2  -5 | 5   0   4   -1   0   0   5
                5   0-10  -25
                0   0 14   24
                      14   24 0
```

Poly Division

```
                          5   0
1   0  -2  -5 | 5   0   4   -1   0   0   5
                5   0-10  -25
                ---------------------------
                0   0 14   24
                      14   24 0
                      14   24 0   0
```

Poly Division

```
                                5   0 14
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
```

Poly Division

```
                          5   0 14
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
          |       14   0 -28 -70
```

Poly Division

```
                                5   0 14
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
          |       14   0 -28 -70
          |-----------------------------
          |       0   24   28   70
```

Poly Division

```
                                5   0 14
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
          |       14   0 -28 -70
          |-----------------------------
          |       0   24   28   70
          |           24   28   70 5
```

Poly Division

```
                                  5   0 14 24
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
          |       14   0 -28 -70
          |-----------------------------
          |       0   24   28   70
          |           24   28   70 5
          |           24   0   -48 -120
```

Poly Division

```
                                  5   0 14 24
1   0 -2 -5 | 5   0   4   -1   0   0   5
          | 5   0-10 -25
          |-----------------------------
          | 0   0 14   24
          |       14   24 0
          |       14   24 0   0
          |       14   0 -28 -70
          |       ---------------------
          |       0   24   28   70
          |           24   28   70 5
          |           24   0   -48 -120
          |           ----------------
          |           0    28 118 125
```

Poly Division

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

$5x^3 + 14x + 24$

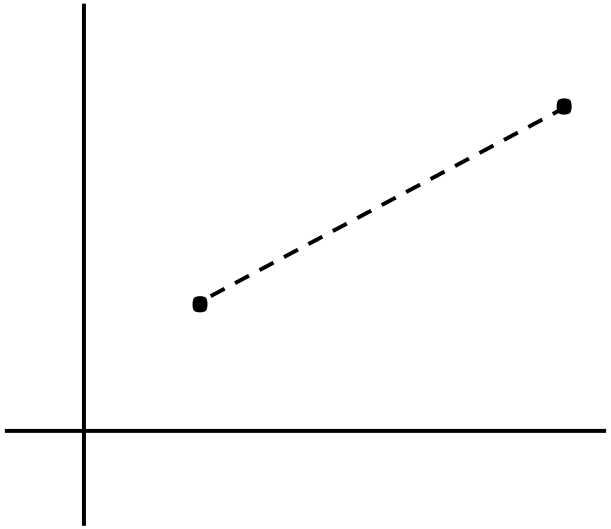
Poly Division

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

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

ADT Example: Line

Suppose we want to make a `Line` class that represents lines on the Cartesian plane



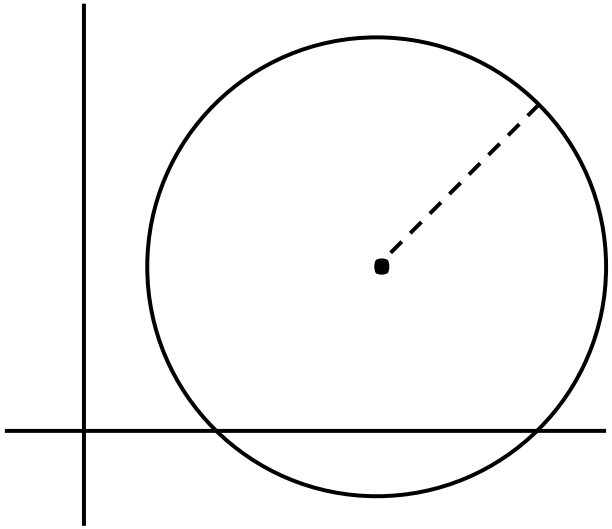
See http://courses.cs.washington.edu/courses/cse331/15sp/concepts/specifications.html for more

ADT Example: Line

```
/**
 * This class represents the mathematical concept of a line segment.
 *
 * A line is an immutable line segment on the 2D plane that has
 * endpoints p1 and p2
 */
public class Line {
…
}
```

ADT Example: Circle

Circle on the Cartesian coordinate plane



Circle: Class Specification

What represents the abstract state of a Circle?

What are some properties of a circle we can determine?

How can we implement this?

What are some ways to “break” a circle?

Representation Invariants

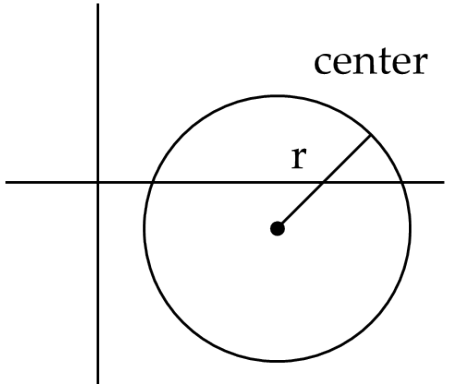
Constrains an object's internal state

Maps concrete representation of object to a boolean

If representation invariant is false/violated, the object is "broken" – doesn't map to any abstract value

Circle Implementation 1

```
public class Circle1 {
        private Point center;
        private double rad;

        // Rep invariant:
        //

        //  ...
}
```

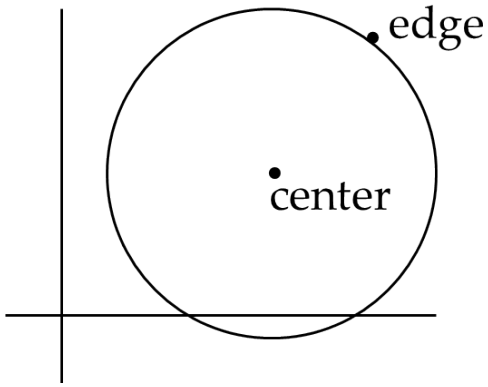


Circle Implementation 1

```
public class Circle1 {
        private Point center;
        private double rad;

        // Rep invariant:
        // center != null && rad > 0

        //  ...
}
```

Circle Implementation 2

```
public class Circle2 {
        private Point center;
        private Point edge;

        // Rep invariant:
        //
        //     ...
}
```

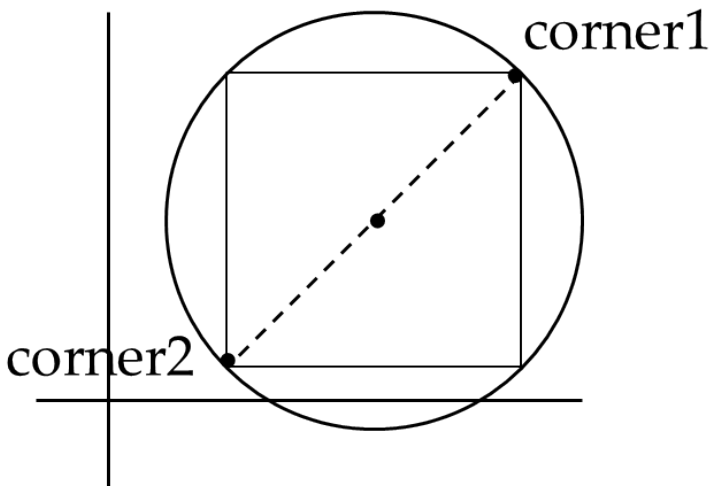


Circle Implementation 2

```
public class Circle2 {
      private Point center;
      private Point edge;

      // Rep invariant:
      // center != null &&
      // edge != null &&
      // !center.equals(edge)
      //    ...
}
```

Circle Implementation 3

```
public class Circle3 {
      private Point corner1, corner2;

      // Rep invariant:
      //
      //    ...
}
```



Circle Implementation 3

```
public class Circle3 {
      private Point corner1, corner2;

      // Rep invariant:
      // corner1 != null &&
      // corner2 != null &&
      // !corner1.equals(corner2)
      //    ...
}
```

Checking Rep Invariants

- Representation invariant should hold before and after every public method

Write and use `checkRep()`

- Call before and after methods that can modify the state
- Can make use of Java's assert syntax (pluses and minuses)
- OK that it adds extra code
  - Code is usually a small part of download size
  - Important for finding bugs

checkRep() Example with Asserts

```
public class Circle1 {
        private Point center;
        private double rad;

        private void checkRep() {
          assert center != null : “This does not have a center”;
          assert radius > 0 : “This circle has a negative radius”;
        }
}
```

A lot neater!

Using Asserts

To enable asserts: Go to Run->Run Configurations…->Arguments tab-> input

- **–ea** in VM arguments section
  - Do this for every test file
  - Demo!