Section 3:
HW4, ADTs, and more

Slides with material from Alex Mariakakis, Krysta Yousoufian, Mike Ernst, Kellen Donohue

Agenda

- HW4: fun with math review!
- Abstract data types (ADTs)
- Method specifications

Polynomial Addition

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

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

Polynomial Multiplication

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

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

Polynomial Division

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

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

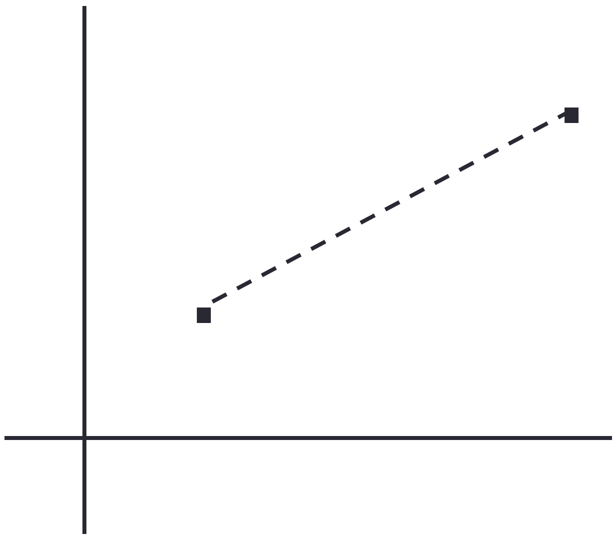
Polynomial Division

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

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

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/cse331/14au/conceptual-info/specifications.html for more

Definitions

- **Abstract Value**: what an instance of a class is supposed to represent
  - `Line` represents a given line
- **Abstract State**: the information that defines the abstract value
  - Each line has a start point and an end point
- **Abstract Invariant:** the conditions (if needed!) that must remain true over the abstract state for all instances
  - Start point and end point must be distinct

Definitions (cont.)

- **Specification Fields**: describes components of the abstract state of a class
  - `Line` has specification fields `startPoint`, `endPoint`
- **Derived Specification Fields**: information that can be derived from specification fields but useful to have
  - `length = sqrt((x1-x2)^2 + (y1-y2)^2)`

ADT Example: Line

```
/**
 * This class represents the mathematical concept of a line segment.
 *
 * Specification fields:
 *  @specfield start-point : point  // The starting point of the line.
 *  @specfield end-point   : point  // The ending point of the line.
 *
 * Derived specification fields:
 *  @derivedfield length : real     // The length of the line.
 *
 * Abstract Invariant:
 *  A line's start-point must be different from its end-point.
 */
public class Line {
…
}
```

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Abstract Value

ADT Example: Line

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Abstract State

ADT Example: Line

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Abstract Invariant

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Specification Fields

ADT Example: Line

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 * Specification fields:
 *  @specfield start-point : point  // The starting point of the line.
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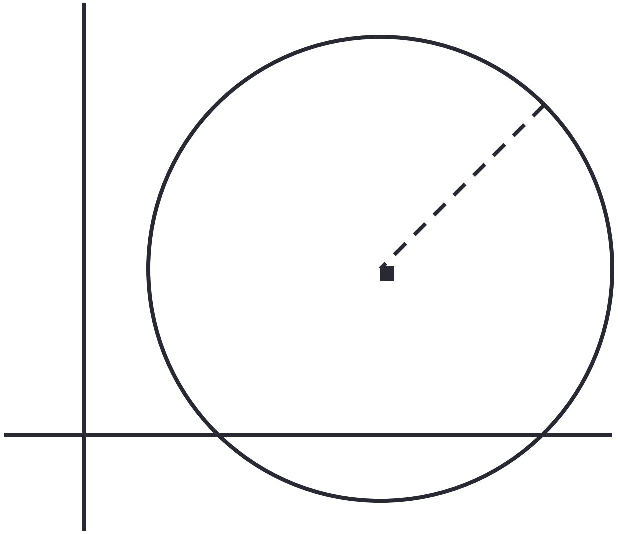
 * Derived specification fields:
 *  @derivedfield length : real     // The length of the line.
 *
 * Abstract Invariant:
 *  A line's start-point must be different from its end-point.
 */
public class Line {
…
}
```

Derived Fields

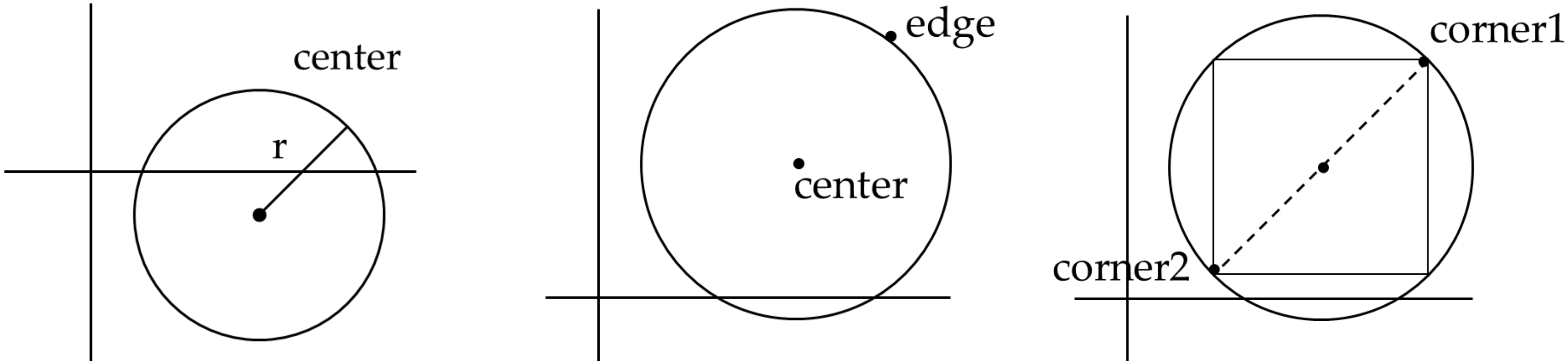
ADT Example: Circle

Suppose we want to make a `Circle` class that represents circles on the Cartesian plane



ADT Example: Circle

- **Abstract Value**:
  - `Circle` represents a given circle
- **Abstract State**:



- **Abstract Invariant**
  - Option #1: r > 0, center must exist
  - Option #2: center and edge must be distinct
  - Option #3: corner1 and corner2 must be distinct

ADT Example: Circle

- **Specification Fields**:
  - Option #1: `r` and `center`
  - Option #2: `center` and `edgePoint`
  - Option #3: `corner1` and `corner2`
- **Derived Specification Fields**:
  - Circumference
  - Diameter
  - Area
  - …

Specification Fields vs. Derived Specfields

- Rectangle: corner1, corner2, length1, length2, area
  - Specification fields:
    - corner1
    - corner2
  - Derived:
    - Length, area
- ShoppingCart: itemlist, total
  - Item: name, quantity, price, total
  - Specification and derived specification?

Abstraction

- Abstract values, state, and invariants specify the behavior of classes and methods
  - What should my class do?
- We have not implemented any of these ADTs yet
  - Implementation should not affect abstract state
  - As long as `Circle` represents the circle we are interested in, nobody cares how it is implemented

Abstract vs. Concrete

- We’ll talk later about **representation invariants**, which specify how the abstract invariant is implemented
  - Boolean: is this a valid instance of our object
  - What does it mean for something to be well-formed?
  - Eg: Date with a negative day
- We’ll also discuss how **abstraction functions** map the concrete representation of an ADT to the abstract value
  - Only defined for things that are well-formed
  - What should the concrete object do, in the abstract view?
  - Eg: what does Date.next do?

Javadoc Documentation

- Tool made by Oracle for API documentation
- We’ve already seen Javadoc for external class specification
- Method specifications will describe method behavior in terms of preconditions and postconditions

Javadoc Method Tags

- **`@requires`**: the statements that must be met by the method's caller
- **`@return`**: the value returned by the method, if any
- **`@throws`**: the exceptions that may be raised, and under which conditions
- **`@modifies`**: the variables that *may* change because of the method
- **`@effects`**: the side effects of the method

Javadoc Method Tags

- If **`@requires`** is not met, anything can happen
  - False implies everything
- The conditions for **`@throws`** must be a subset of the precondition
  - Ex: If a method **`@requires`** x > 0, **`@throws`** should not say anything about
    x < 0
- **`@modifies`** lists *what* may change, while **`@effects`** indicates *how* they change
  - If a specification field is listed in the **`@modifies`** clause but not in the **`@effects`** clause, it may take on any value (provided that it follows the abstract invariant)
  - If you mention a field in **`@modifies`**, you should try to specify what happens in **`@effects`**

JAVADOC DEMO!

Polynomial practice!

- $(x^2 + 3x + 5) - (4x^3 – 2x^2 + 3x - 2)$
  - $-4x^3 + 3x^2 + 7$
- $(x^3 – 3x + 1) * (x - 3)$
  - $x^4 - 3x^3 – 3x^2 + 10x -3$
- $(3x^3 – 2x^2 + 4x -3) / (x^2 + 3x + 3)$
  - $(3x – 11)$, remainder $(28x + 30)$