CSE 331
Software Design & Implementation

Autumn 2022

Section 6 – HW6 and Midterm Review

Administrivia

- Done with HW5!
- HW6 (ADT implementation) due next week (**Thurs**. 11/10)
  - We will get feedback out for you early next week
- Midterm tomorrow during lecture!
- Any questions?

Agenda

- Walk-through of the test-script driver (to run **`.test`** files)
- Managing an expensive **`checkRep`**
- Midterm review

Refresher: Format of script tests

Each script test is expressed as text-based script ***foo*.test**

- One command per line, of the form: **Command** arg_1 arg_2 …
- Script's output compared against ***foo*.expected**
- Precise details specified in the homework
- Match format ***exactly***, including whitespace!

Command (in *foo*.test)	Output (in *foo*.expected)
CreateGraph *name*	**created graph** *name*
AddNode *graph label*	**added node** *label* **to** *graph*
AddEdge *graph parent child label*	**added edge** *label* **from** *parent* **to** *child* **in** *graph*
ListNodes *graph*	*graph* **contains:** $label_{node}$ …
ListChildren *graph parent*	**the children of** *parent* **in** *graph* **are:** *child* **(**$label_{edge}$**)** …
# *This is comment text …*	**#** *This is comment text …*

Refresher: `example.test`

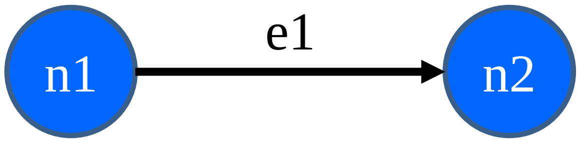
```
# Create a graph
CreateGraph graph1

# Add a pair of nodes
AddNode graph1 n1
AddNode graph1 n2

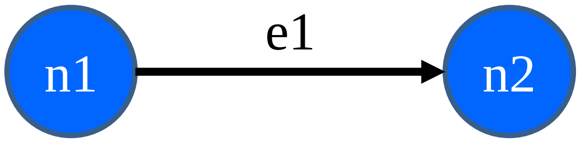
# Add an edge
AddEdge graph1 n1 n2 e1

# Print all nodes in the graph
ListNodes graph1

# Print all child nodes of n1 with outgoing edge
ListChildren graph1 n1
```



Refresher: `example.expected`




```
# Create a graph
created graph graph1

# Add a pair of nodes
added node n1 to graph1
added node n2 to graph1

# Add an edge
added edge e1 from n1 to n2 in graph1

# Print all nodes in the graph
graph1 contains: n1 n2

# Print all child nodes of n1 with outgoing edge
the children of n1 in graph1 are: n2(e1)
```

How the script tests work

- In HW5, you wrote script tests in the form of **`.test`** files
  - As well as an **`.expected`** file for each test's expected outcome
- The JUnit class **`ScriptFileTests`** runs all these tests
  - Looks for all the **`.test`** files in the **`src/test/resources/testScripts`** folder
  - Compares test output against corresponding **`.expected`** file
- **`ScriptFileTests`** needs a bridge to your graph implementation
  - That's exactly what the **`GraphTestDriver`** class is for

Graph Test Driver

- **`GraphTestDriver`** knows how to read these test scripts

- **`GraphTestDriver`** calls a method to “do” each verb
  - **`CreateGraph`**, **`AddNode`**, **`AddEdge`** …
  - One method stub per script command for you to fill with calls to your graph code

- Note: Completed test driver should sort lists before printing for **`ListNodes`** and **`ListChildren`**
  - Just to ensure predictable, deterministic output
  - Your graph implementation itself should not worry about sorting

Graph Test Driver Output

- The Graph Test Driver is a client of our graph…
  - …but not the only client.
  - Your graph should not be designed to be exclusively used for the test driver.
- ListChildren in the test driver should print out: "**`the children of`** *parent* **`in`** *graph* **`are:`** *child* **`(`**$label_{edge}$**`)`** …"
- This does **not** mean that you should have a method on your graph called ListChildren that returns this String
  - Because that isn't useful for other clients

Sorting with the driver

- **Use the test driver appropriately!**
  - From before: “Completed test driver should sort lists before printing.”

- Script test output for hw5 needs to be sorted so we can mechanically check it.

- This means sorted output for tests does ***NOT*** mean sorted internal storage in graph.
  - If sorting behavior is needed, Graph ADT clients (including the test driver) can sort those labels.

In other words…

The Graph ADT in general should ***NOT*** assume that node or edge labels are sorted or even comparable(!).

(of course they can be tested for equality with equals())

Demo

Here's a quick tour of the **`GraphTestDriver`**!

Expensive **`checkRep`**s

- A complicated rep. invariant can be expensive to check
  - Especially iterating over internal collection(s)
  - For example, examining every edge in a graph
- A slow **`checkRep`** could cause our grading scripts to time-out
  - Can be really useful during testing/debugging, but
  - Need to disable the really slow checks <u>before submitting</u>
- We have a tension between two goals:
  - Thorough, possibly slow checking for development
  - Essential, necessarily fast checking for production/grading
- What to do?

Use a debug flag to tune `checkRep`

- Repeatedly (un)commenting sections of code is a poor solution

- Instead, use a class-level constant as a toggle
  - Ex.: **`private static final boolean DEBUG = …;`**
    - **`false`** for only the fast, essential checks
    - **`true`** for all the slow, thorough checks
  - Real-world code often has several such “debug levels”

```
private void checkRep() {
    assert fast_checks();
    if (DEBUG)
        assert slow_checks();
}
```

Midterm Review

intToString()

Fill in the implementation of a method that converts a **positive integer** to its **string representation in decimal** (invariant given on next slide).

```
{{ P: x > 0 }}
String intToString(int x)
```

Useful facts to recall:

1. Convert **`char ch`** that is one of **`'0','1',…,'9'`** to a corresponding int by doing **`ch – '0'`**
2. Convert **`int x`** that is one of **`0,1,…,9`** to a corresponding char by doing **`(char) (x + '0')`**

intToString()

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf =
  int k =  , y =  ;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {




   k = k + 1;
  }

  return buf.reverse().toString();
}
```

How do we get the invariant to hold initially?

intToString()

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {



   k = k + 1;
  }

  return buf.reverse().toString();
}
```

How do we fill out the loop body?

intToString()

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {



   k = k + 1;
  }

  return buf.reverse().toString();
}
```

Inv changes k to k+1, so

- y becomes $x / 10^{k+1}$
- $y_{post} = x / 10^{k+1} = y_{pre} / 10$

`intToString()`

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{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {


   y = y / 10;
   k = k + 1;
  }

  return buf.reverse().toString();
}
```

Inv changes k to k+1, so

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   y = y / 10;
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intToString()

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{{ P: x > 0 }}
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  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
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  while (y != 0) {



   y = y / 10;
   k = k + 1;
  }

  return buf.reverse().toString();
}
```

Inv changes k to k+1, so

- buf stores lowest k+1 digits

(k+1)-st lowest digit goes at end since buf stores them reversed

intToString()

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {
   char ch = ?
   buf.append(ch);
   y = y / 10;
   k = k + 1;
  }

  return buf.reverse().toString();
}
```

How can we get the (k+1)-st lowest digit of x? And make it a char?

intToString()

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {
   char ch = (char) (y % 10 + '0');
   buf.append(ch);
   y = y / 10;
   k = k + 1;
  }

  return buf.reverse().toString();
}
```

`intToString()` solution

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {
   char ch = (char) (y % 10 + '0');
   buf.append(ch);
   y = y / 10;
   k = k + 1;
  }
  {{ buf stores the digits of x in reverse order }}
  return buf.reverse().toString();
}
```

Why does this hold?

`intToString()` solution

```
{{ P: x > 0 }}
String intToString(int x) {
  StringBuilder buf = new StringBuilder();
  int k = 0, y = x;
  {{ Inv: P and buf stores the lowest k digits of x
          in reverse order and y = x / 10^k }}
  while (y != 0) {
   char ch = (char) (y % 10 + '0');
   buf.append(ch);
   y = y / 10;
   k = k + 1;
  }
  {{ buf stores the digits of x in reverse order }}
  return buf.reverse().toString();
}
```

Why does this hold?
$y = 0 \Rightarrow x < 10^k$ so x only has k digits

Specifications

Suppose we have a **`BankAccount`** class with instance variable balance. Consider the following specifications (ignore **`@param`**):

```
A. @effects decreases balance by amount
B. @requires amount >= 0 and amount <= balance
   @effects decreases balance by amount
C. @throws InsufficientFundsException if balance < amount
   @effects decreases balance by amount
```

(A ✓, B ✓, C ✗)

Which specifications does this implementation meet?

```
void withdraw(int amount) {
   balance -= amount;
}
```

Specifications

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   @effects decreases balance by amount
C. @throws InsufficientFundsException if balance < amount
   @effects decreases balance by amount
```

Which specifications does this implementation meet?

```
void withdraw(int amount) {
   if (balance >= amount) balance-=amount;
}
```

Specifications

Suppose we have a **`BankAccount`** class with instance variable balance. Consider the following specifications (ignore **`@param`**):

```
A. @effects decreases balance by amount
B. @requires amount >= 0 and amount <= balance
   @effects decreases balance by amount
C. @throws InsufficientFundsException if balance < amount
   @effects decreases balance by amount
```

Which specifications does this implementation meet?

```
void withdraw(int amount) {
   if (amount < 0) throw new IllegalArgumentException();
   balance -= amount;
}
```

Specifications

Suppose we have a **`BankAccount`** class with instance variable balance. Consider the following specifications (ignore **`@param`**):

```
A. @effects decreases balance by amount                          ✗
B. @requires amount >= 0 and amount <= balance
   @effects decreases balance by amount                          ✓
C. @throws InsufficientFundsException if balance < amount
   @effects decreases balance by amount                          ✓
```

Which specifications does this implementation meet?

```
void withdraw(int amount) throws InsufficientFundsException {
   if (balance < amount) throw new InsufficientFundsException();
   balance -= amount;
}
```

Testing

Consider the **`BankAccount`** class again. What are some good test cases?

```
public class BankAccount {
  /** @return current balance of account */
  public void balance() { … }

  /**
   * @param amount to withdraw
   * @requires amount >= 0
   * @throws InsufficientFundsException
   *         if balance < amount
   * @effects decreases balance by amount
   */
  public void withdraw(int amount) { … }
}
```

Specification test heuristic:

- amount <= balance
- amount > balance

Boundary test heuristic:

- amount = balance
- amount > balance

Others?

Should we test amount < 0?

More Reasoning

Let's check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ ? }}
    xk = xk * x;
    {{ ? }}
    val = val + a[k+1]*xk;
    {{ ? }}

    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

More Reasoning

Let's check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ ? }}
    xk = xk * x;
    {{ ? }}
    val = val + a[k+1]*xk;
    {{ ? }}

    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

Does the invariant hold before the loop?

More Reasoning

Let's check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ ? }}
    xk = xk * x;
    {{ ? }}
    val = val + a[k+1]*xk;
    {{ ? }}

    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

More Reasoning

Let's check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ inv && k != n }}
    xk = xk * x;
    {{ ? }}
    val = val + a[k+1]*xk;
    {{ ? }}

    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

More Reasoning

Let's check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ inv && k != n }}
    xk = xk * x;
    {{ xk = x^(k+1) && val = a[0] + a[1]*x + … + a[k]*x^k && k != n }}
    val = val + a[k+1]*xk;
    {{ ? }}

    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

More Reasoning

Let’s check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ inv && k != n }}
    xk = xk * x;
    {{ xk = x^(k+1) && val = a[0] + a[1]*x + … + a[k]*x^k && k != n }}
    val = val + a[k+1]*xk;
    {{ xk = x^(k+1) && val = a[0] + a[1]*x + … + a[k+1]*x^(k+1)
                                                            && k != n }}
    k = k + 1;
    {{ ? }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

More Reasoning

Let’s check that this method is correct.

```
/** Return the value of this IntPoly at point x */
public int valueAt(int x) {
  int val = a[0];
  int xk = 1;
  int k = 0;
  int n = a.length - 1;
  {{ inv: xk = x^k && val = a[0] + a[1]*x + … + a[k]*x^k }}
  while (k != n) {
    {{ inv && k != n }}
    xk = xk * x;
    {{ xk = x^(k+1) && val = a[0] + a[1]*x + … + a[k]*x^k && k != n }}
    val = val + a[k+1]*xk;
    {{ xk = x^(k+1) && val = a[0] + a[1]*x + … + a[k+1]*x^(k+1)
                                                            && k != n }}
    k = k + 1;
    {{ inv && k-1 != n }} -> {{ inv }}
  }
  {{ val = a[0] + a[1]*x + … + a[n]*x^n }}
  return val;
}
```

Do we reach the postcondition?

Good luck on the midterm!