CompSci 6
Programming Design and Analysis

Loop Invariants

March 4, 2010

Prof. Rodger

Announcements

- Today –
  - – Loop Invariants
  - – Finish Inheritance classwork from March 2
  - – New Classwork for loop invariants
  - – Turn in BOTH classworks by March 16!
- Reading Quiz for next time
- Read Chapter 7.6

Assignment 6 - Breakout

- Go over code

Patterns

"Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem,in such a way that you can use this solution a million times over, without ever doing it the same way twice”

- – Alexander et. al, 1977
- – A text on architecture!

•What is a programming or design pattern?

•Why are patterns important?

What is a pattern?

- "… a three part rule, which expresses a relation between a certain context, a problem, and a solution. The pattern is, in short, at the same time a thing, … , and the rule which tells us how to create that thing, and when we must create it."
  Christopher Alexander
  – name
  – problem
  – solution
  – consequences
- more a recipe than a plan, micro-architecture, frameworks, language idioms made abstract, less than a principle but more than a heuristic
- patterns capture important practice in a form that makes the practice accessible

Patterns are discovered, not invented

- You encounter the same "pattern" in developing solutions to programming or design problems
  – develop the pattern into an appropriate form that makes it accessible to others
  – fit the pattern into a language of other, related patterns

- Patterns transcend programming languages, but not (always) programming paradigms
  – OO folk started the patterns movement
  – language idioms, programming templates, programming patterns, case studies

Programming Problems

- Microsoft interview question (1998)

3	3	5	5	7	8	8	8

- Dutch National Flag problem (1976)

🟥	⬜	🟦	🟦	🟥	⬜	🟦	⬜	🟥
🟥	🟥	🟥	⬜	⬜	⬜	🟦	🟦	🟦

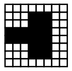
- Remove Zeros (AP 1987)

2	1	0	5	0	0	8	4

- Quicksort partition (1961, 1986)

4	3	8	9	1	6	0	5
3	1	0	4	8	9	6	5

- Run-length encoding (SIGCSE 1998)



11 3 5 3 2 6 2 6 5 3 5 3 5 3 10

Loop Invariant

- What is true
  – Before the loop
  – During the loop
    - Each time before the body is started
  – After the loop

Example 1 – Find max in array

- What is the loop invariant?

```
ArrayList<Integer> values;
…
int max = 0;
for (int k=0; k < values.size(); k++)
{
    if (values.get(k) > max)
           max = values.get(k);
}
```

Example 2

- Find the max (all of them if there are several) and put them at the front of the array. The order of the other elements doesn't matter.
- Sample input and output
  - Start: 7 3 6 9 2 8 9 9 4
  - End: 9 9 9 7 2 8 3 6 4
- Return the position of the last max

Example 2 (cont)

- What is the loop invariant?

```
ArrayList<Integer> values;
…
int maxPos = 0;
for (int k=0; k < values.size(); k++)
{
  if (values.get(k)>values.get(maxPos))
  {
           maxPos = 0;
           Swap(k, maxPos);
  }
```

Example 2 (cont)

```
else if
  (values.get(k)==values.get(maxPos))
  {
           maxPos ++;
           Swap(k, maxPos);
  }
}
return maxPos;
```

Example 3 - Removing Duplicates

```
void crunch(ArrayList<String> list)
{   // assume list is sorted, may have duplicates
  int lastUniqueIndex = 0;
  String lastUnique = list.get(0);
  for(int k=1; k < list.size(); k++)
  {
    String current = list.get(k);
    if (current != lastUnique)
    {
      list.set(++lastUniqueIndex, current);
      lastUnique = current;
    }
  }
  for (int k=list.size()-1; k > lastUniqueIndex; k--)
      list.remove(k);
}
```

One loop for linear structures

- Algorithmically, a problem may seem to call for multiple loops to match intuition on how control structures are used to program a solution to the problem, but data is stored sequentially, e.g., in an array or file. Programming based on control leads to more problems than programming based on structure.
  Therefore, use the structure of the data to guide the programmed solution: one loop for sequential data with appropriately guarded conditionals to implement the control

  Consequences: one loop really means loop according to structure, do not add loops for control: what does the code look like for run-length encoding example?

What about efficiency?

Coding Pattern

- Name:
  - one loop for linear structures
- Problem:
  - Sequential data, e.g., in an array or a file, must be processed to perform some algorithmic task. At first it may seem that multiple (nested) loops are needed, but developing such loops correctly is often hard in practice.
- Solution:
  - Let the structure of the data guide the coding solution. Use one loop with guarded/if statements when processing one-dimensional, linear/sequential data
- Consequences:
  - Code is simpler to reason about, facilitates develop of loop invariants, possibly leads to (slightly?) less efficient code

Classwork Today

- APT
  - Run Length Encoding