Specifications

CSE 331

Spring 2010

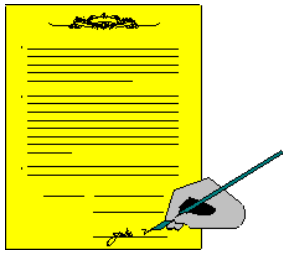
The challenge of scaling software

- Small programs are simple and malleable
  - easy to write
  - easy to change
- Big programs are (often) complex and inflexible
  - hard to write
  - hard to change
- Why does this happen?
  - Because interactions become unmanageable
- How do we keep things simple and malleable?

A discipline of modularity

- Two ways to view a program:
  - The implementor's view (how to build it)
  - The client's view (how to use it)
- It helps to apply these views to program *parts:*
  - While implementing one part, consider yourself a client of any other parts it depends on
  - Try *not* to look at those other parts through an implementor's eyes
  - This helps dampen interactions between parts
- Formalized through the idea of a specification

A specification is a contract



- A set of requirements agreed to by the user and the manufacturer of the product
  - describes their expectations of each other
- Facilitates simplicity by *two-way* isolation
  - Isolate client from implementation details
  - Isolate implementor from how the part is used
  - Discourages implicit, unwritten expectations
- Facilitates change
  - Reduces the “Medusa” effect: the specification, rather than the code, gets “turned to stone” by client dependencies

Isn't the interface sufficient?

The interface is to defines the boundary between the implementers and users:

```
public interface List<E> {
        public int get(int);
        public void set(int, E);
        public void add(E);
        public void add(int, E);
        …
        public static boolean sub(List<T>, List<T>);
}
```

Interface provides the syntax

But nothing on the behavior and effects

Why not just read code?

```
boolean sub(List<?> src, List<?> part) {
    int part_index = 0;
    for (Object o : src) {
        if (o.equals(part.get(part_index))) {
            part_index++;
            if (part_index == part.size()) {
                return true;
            }
        } else {
            part_index = 0;
        }
    }
    return false;
}
```

Why are you better off with a specification?

Code is complicated

- Code gives more detail than needed by client
- Understanding or even reading every line of code is an excessive burden
  - Suppose you had to read source code of Java libraries in order to use them
  - Same applies to developers of different parts of the libraries
- Client cares only about what the code does, not how it does it

Code is ambiguous

- Code seems unambiguous and concrete
  - But which details of code's behavior are essential, and which are incidental?
- Code invariably gets rewritten
  - Client needs to know what they can rely on
    - what properties will be maintained over time?
    - what properties might be changed by future optimization, improved algorithms, or just bug fixes?
  - Implementor needs to know what features the client depends on, and which can be changed

Comments are essential

- *Most comments convey only an informal, general idea of what that the code does:*

```
// This method checks if "part" appears as a
// sub-sequence in "src"
boolean sub(List<?> src, List<?> part) {
        ...
}
```

- *Problem: ambiguity remains*
  - *e.g. what if src and part are both empty lists?*

From vague comments to specifications

- ***Properties of a specification:***
  - The client agrees to rely *only* on information in the description in their use of the part.
  - The implementor of the part promises to support everything in the description, but otherwise is perfectly at liberty
- ***Sadly, much code lacks a specification***
  - Clients often work out what a method/class does in ambiguous cases by simply running it, then depending on the results
  - This leads to bugs and to programs with unclear dependencies, reducing simplicity and flexibility

Recall the sublist example

```
T boolean sub(List<T> src, List<T> part) {
    int part_index = 0;
    for (T elt : src) {
        if (elt.equals(part.get(part_index))) {
            part_index++;
            if (part_index == part.size()) {
                return true;
            }
        } else {
            part_index = 0;
        }
    }
    return false;
}
```

a more careful description of sub()

// Check whether "part" appears as a
// sub-sequence in "src".

needs to be given some caveats (why?):

// * src and part cannot be null
// * If src is empty list, always returns false.
// * Results may be unexpected if partial matches
// can happen right before a real match; e.g.,
// list (1,2,1,3) will not be identified as a
// sub sequence of (1,2,1,2,1,3).

or replaced with a more detailed description:

// This method scans the "src" list from beginning
// to end, building up a match for "part", and
// resetting that match every time that...

It's better to simplify than to describe complexity

- Complicated description suggests poor design
  - Rewrite sub() to be more sensible, and easier to describe. Then a good description would be:

```
// returns true iff sequences A, B exist such that
//   src = A : part : B
// where ":" is sequence concatenation
boolean sub(List<?> src, List<?> part)
```

- This is a decent specification
  - Mathematical flavor is not necessary, but can help avoid ambiguity

sneaky fringe benefit of specs #1

- The discipline of writing specifications changes the incentive structure of coding
  - rewards code that is easy to describe and understand
  - punishes code that is hard to describe and understand (even if it is shorter or easier to write)
- If you find yourself writing complicated specifications, it is an incentive to redesign
  - sub() code that does exactly the right thing may be slightly slower then hack that assumes no partial matches before true matches – but cost of forcing client to understand the details is too high

examples of specifications

- Javadoc
  - Sometimes can be daunting; get used to using it
- Javadoc convention for writing specifications
  - method prototype
  - text description of method
  - param – description of what gets passed in
  - returns – description of what gets returned
  - throws – list of exceptions that may occur

example: Javadoc for String.contains

public boolean contains(CharSequence s)

Returns true if and only if this string contains the specified sequence of char values.

Parameters:

s- the sequence to search for

Returns:

true if this string contains s, false otherwise

Throws:

NullPointerException

Since:

1.5

CSE 331 specifications

- The "precondition": constraints that hold before the method is called (if not, all bets are off)
  - requires – spells out any obligations on client
- The "postcondition": constraints that hold after the method is called (if the precondition held)
  - modifies – lists objects that may be affected by method; any object not listed is guaranteed to be untouched
  - throws – lists possible exceptions (Javadoc uses this too)
  - effects – gives guarantees on the final state of modified objects
  - returns –describes return value (Javadoc uses this too)

Example 1

static int test(List<T> lst, T oldelt, T newelt)

requires	lst, oldelt and newelt are non null. oldelt occurs in lst
modifies	lst
effects	change the first occurrence of oldelt in lst to newelt & makes no other changes to lst
returns	the position of the element on lst that was oldelt and now newelt

```
static int test(List<T> lst, T oldelt, T newelt) {
    int i = 0;
    for (T curr : lst) {
        if (curr == oldelt) {
                lst.set(newelt, i);
                return i;
        }
       i = i + 1;
    }
    return -1;
}
```

Example 2

static List<Integer> listAdd(List<Integer> lst1, List<Integer> lst2)

requires	lst1 and lst2 are not null. lst1 and lst2 are the same size
modifies	none
effects	none
returns	a list of same size where the ith element is the sum of the ith elements of lst1 and lst2

```
static List<Integer> listAdd( List<Integer> lst1,
                              List<Integer> lst2) {
        List<Integer> res = new ArrayList<Integer>();
        for(int i = 0; i < lst1.size(); i++) {
                res.add(lst1.get(i) + lst2.get(i));
        }
        return res;
}
```

Example 3

static void listAdd2(List<Integer> lst1, List<Integer> lst2)

requires	lst1 and lst2 are not null. lst1 and lst2 are the same size
modifies	lst1
effects	ith element of lst2 is added to the ith element of lst1
returns	none

```
static void listAdd2(List<Integer> lst1,
                     List<Integer> lst2) {
      for(int i = 0; i < lst1.size(); i++) {
            lst1.set(i, lst1.get(i) + lst2.get(i));
      }
  }
```

example: java.util.Arrays.binarySearch

binarySearch

public static int binarySearch(int[] a,int key)

Searches the specified array of ints for the specified value using the binary search algorithm. The array must be sorted (as by the `sort` method, above) prior to making this call. If it is not sorted, the results are undefined. If the array contains multiple elements with the specified value, there is no guarantee which one will be found.

Parameters:

`a`- the array to be searched.

`key`- the value to be searched for.

Returns:

index of the search key, if it is contained in the list; otherwise, `( -(insertion point) - 1)`. (long description...)

Improved binarySearch

public static int **binarySearch**(int[] a,int key)

requires: a is sorted in ascending order

returns:

- some i such that a[i] = key if such an i exists,
- otherwise -1

(Returning `(-(`*`insertion point`*`) - 1)` *is very ugly, and an invitation to bugs and confusion; please read full specification and think about why the designers did this, and what the alternatives are. We'll return to the topic of exceptions and special values in a later lecture.)*

Should requires clause be checked?

- If the client calls a method without meeting the precondition, the code is free to do anything, including pass corrupted data back
  - It is polite, nevertheless, to *fail-fast: to provide an immediate error, rather than simply letting mysterious bad stuff happen*
- Preconditions used more in "helper" methods/classes rather than public libraries – friendlier to just deal with all possible input
  - *Why does binarySearch impose a precondition rather than simply failing if list is not sorted?*
- Rule of Thumb: Check if cheap to do so
  - *Ex: list has to be non-null → check*
  - *Ex: list has to be sorted → skip*

Comparing specifications

- Occasionally, we need to compare different versions of a specification
  - For that, we talk about “weaker” and “stronger” specifications
- Intuitively, we weaken a specification when we change it to give greater freedom to the implementor
  - If specification S_1 is weaker than S_2, then for any implementation I,
    - I satisfies S_2 => I satisfies S_1
    - but the opposite implication does not hold in general

Example 1

```
int find(int[] a, int value) {
    for (int i=0; i<a.length; i++) {
        if (a[i]==value) return i;
    }
    return -1;
}
```

- specification A
  - requires: value occurs in a
  - returns: i such that a[i] = value
- specification B
  - requires: value occurs in a
  - returns: smallest i such that a[i] = value

Example 2

```
int find(int[] a, int value) {
    for (int i=0; i<a.length; i++) {
        if (a[i]==value) return i;
    }
    return -1;
}
```

- specification A
  - requires: value occurs in a
  - returns: i such that a[i] = value
- specification C
  - returns: i such that a[i]=value, or -1 if value is not in a

Stronger and weaker specifications

- A stronger specification is
  - Harder to satisfy (harder to implement)
  - Easier to use (more guarantees, more predictable)
- A weaker specificaton is
  - Easier to satisfy (easier to implement, more implementations satisfy it)
  - Harder to use (makes fewer guarantees)

Strengthening a specification

- strengthen a specification by:
  - promising more
    - effects clause harder to satisfy, and/or fewer objects in modifies clause)
  - asking less of client
    - requires clause easier to satisfy
- weaken a specification by:
  - promising less
    - effects clause easier to satisfy, and/or extra objects in modifies clause
  - asking more of the client
    - requires clause harder to satisfy

Choosing specifications

- There are different specifications for the same implementation?
  - Specification says more than method does
  - Declares which properties are essential – the method itself leaves that ambiguous
  - Clients know what they can rely on, implementors know what they are committed to
- Which is *better*: a strong or a weak specification?
  - It depends!
  - Criteria: simple, promotes reuse & modularity, efficient

Sneaky fringe benefit of specs #2

- Specification means that client doesn't need to look at implementation
  - So code may not even exist yet!
- Write specifications first, make sure system will fit together, and then assign separate implementors to different modules
  - Allows teamwork and parallel development (this is crucial, as you'll see towards the end of term)
  - Also helps with testing, as we'll see shortly