SE 2AA4, CS 2ME3 (Introduction to Software Development)

Winter 2018

29 Introduction to Verification (Ch. 6)

Dr. Spencer Smith

Faculty of Engineering, McMaster University

March 21, 2018

29 Introduction to Verification (Ch. 6)

- Partially based on slides by Dr. Wassyng, Ghezzi et al
- Administrative details
- pointInRegion(p)
- Outline of verification topics
- Testing so far in SFWR ENG 2AA4
- Need for verification
- Properties and approaches to verification
- Goals of testing
- Test plan
- Types of test - white box, versus black box, manual versus automated, etc.

Administrative Details

- A3
  - Part 2 - Code: due 11:59 pm Mar 26
- A4
  - Due April 9 at 11:59 pm

Advantages of Tables

- Tabular expressions describe relations through pre and post conditions - ideal for describing behaviour without sequences of operations
- They make it easy to ensure input domain coverage
- They are easy to read and understand (you need just a little practise to write them)
- Coding from tables results in extremely well structured code
- They facilitate identification of test cases
- Extremely good for real-time/embedded systems

A Table for pointInRegion(p)

- Consider all of the cases for a rectangle
- Draw a picture
- Short form notation
  - $px = p.\text{xcoord}()$
  - $py = p.\text{ycoord}()$
  - $llx = lower\_left.\text{xcoord}()$
  - $lly = lower\_left.\text{ycoord}()$
  - $llxw = lower\_left.\text{xcoord}() + width$
  - $llyh = lower\_left.\text{ycoord}() + height$
  - $\text{T} = \text{Constants.TOLERANCE}$
  - $p1.\text{dist}(p2)$ is the distance between p1 and p2

		out

		out
$px < llx$		
$llx \leq px \leq llxw$		
$px > llxw$		

		out
$px < llx$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \mathrm{T}$
	$py > llyh$	
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)) \leq \mathrm{T}$
$llx \leq px \leq llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)) \leq \mathrm{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \text{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	$(py - llyh) \leq \text{T}$
$px > llxw$	$py < lly$	
	$lly \leq py \leq llyh$	
	$py > llyh$	

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)) \leq \mathrm{T}$
$llx \leq px \leq llxw$	$py < lly$	$(lly - py) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	True
	$py > llyh$	$(py - llyh) \leq \mathrm{T}$
$px > llxw$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, llyh)) \leq \mathrm{T}$

Seven Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$

Seven Cases

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(llx - px) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)) \leq \mathrm{T}$
$llx \leq px \leq llxw$		$(lly - \mathrm{T}) \leq py \leq (llyh + \mathrm{T})$
$px > llxw$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, lly)) \leq \mathrm{T}$
	$lly \leq py \leq llyh$	$(px - llxw) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, llyh)) \leq \mathrm{T}$

Six Cases

		out
$px < llx$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llx, lly)) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)) \leq \mathrm{T}$
$llx \leq px \leq llxw$		$(lly - \mathrm{T}) \leq py \leq (llyh + \mathrm{T})$
$px > llxw$	$py < lly$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, lly)) \leq \mathrm{T}$
	$py > llyh$	$p.\mathrm{dist}(\mathrm{PointT}(llxw, llyh)) \leq \mathrm{T}$
$lly \leq py \leq llyh$		

Six Cases

		out
$px < llx$	$py < lly$	$p.\text{dist}(\text{PointT}(llx, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llx, llyh)) \leq \text{T}$
$llx \leq px \leq llxw$		$(lly - \text{T}) \leq py \leq (llyh + \text{T})$
$px > llxw$	$py < lly$	$p.\text{dist}(\text{PointT}(llxw, lly)) \leq \text{T}$
	$py > llyh$	$p.\text{dist}(\text{PointT}(llxw, llyh)) \leq \text{T}$
$lly \leq py \leq llyh$		$(llx - \text{T}) \leq px \leq (llxw + \text{T})$

Three Cases

	out
$llx \leq px \leq llxw$	$(lly - \mathsf{T}) \leq py \leq (llyh + \mathsf{T})$
$lly \leq py \leq llyh$	$(llx - \mathsf{T}) \leq px \leq (llxw + \mathsf{T})$
$\neg(llx \leq px \leq llxw) \wedge \neg(lly \leq py \leq llyh)$	

Three Cases

	out
$llx \leq px \leq llxw$	$(lly - \mathrm{T}) \leq py \leq (llyh + \mathrm{T})$
$lly \leq py \leq llyh$	$(llx - \mathrm{T}) \leq px \leq (llxw + \mathrm{T})$
$\neg(llx \leq px \leq llxw) \wedge \neg(lly \leq py \leq llyh)$	$\min[p.\mathrm{dist}(\mathrm{PointT}(llx, lly)), p.\mathrm{dist}(\mathrm{PointT}(llxw, lly)), p.\mathrm{dist}(\mathrm{PointT}(llx, llyh)), p.\mathrm{dist}(\mathrm{PointT}(llxw, llyh))] \leq \mathrm{T}$

Nine Cases, but 2D

- How would you write all 9 cases, but with a tabular form that closely matches the original 2D problem description?

Outline of Verification Topics

- What are the goals of verification?
- What are the main approaches to verification?
  - What kind of assurance do we get through testing?
  - Can testing prove correctness?
  - How can testing be done systematically?
  - How can we remove defects (debugging)?
- What are the main approaches to software analysis?
- Informal versus formal analysis

Testing on Assignment 1 to 3

- Limited guidance on test case selection
- Maybe improved test cases would improve the results?
- Consider the method for deleting from a sequence of T (next slide)
- We have been using automated testing
- We have seen the advantages of regression testing
- Some have adopted the excellent strategy of testing while developing
  - Helps isolate errors
  - Does not leave testing to the end when there is no time to do it properly
  - Helps improve the understanding of the problem and the program
- Hopefully the experience on the assignments has motivated you to think more about testing

Incorrect Version of Delete

Using `s = new T[MAX_SIZE]`, for some type `T`

```
public static void del(int i)
{
  int j;

  for (j = i; j <= (length - 1); j++)
  {
    s[j] = s[j+1];
  }

  length = length - 1;
}
```

- What is the error?
- What test case would highlight the error?

Correct Version of Delete

```
public static void del(int i)
{
  int j;

  for (j = i; j < (length - 1); j++)
  {
    s[j] = s[j+1];
  }

  length = length - 1;
}
```

Avoids potential ArrayIndexOutOfBoundsException Exception

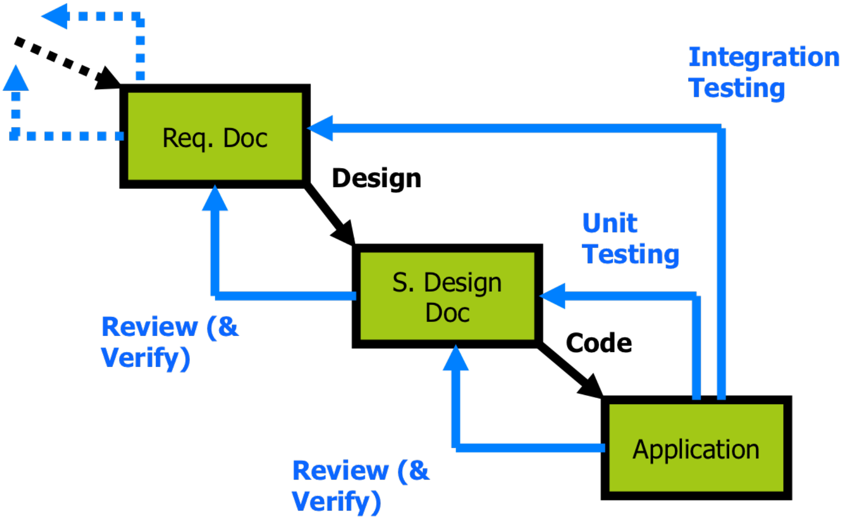
Verification Versus Validation

- What is the difference between verification and validation?

Verification Versus Validation

- Verification - Are we building the product right? Are we implementing the requirements correctly (internal)
- Validation - Are we building the right product? Are we getting the right requirements (external)
- According to Capability Maturity Model (CMM)
  - Software Verification: The process of evaluating software to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase. [IEEE-STD-610]
  - Software Validation: The process of evaluating software during or at the end of the development process to determine whether it satisfies specified requirements. [IEEE-STD-610]
- We will focus on verification

Verification Activities



Need for Verification

- Designers are fallible even if they are skilled and follow sound principles
- We need to build confidence in the software
- Everything must be verified, every required functionality, every required quality, every process, every product, every document
- For every work product covered in this class we have discussed its verification
- Even verification itself must be verified

Properties of Verification

- May not be binary (OK, not OK)
  - Severity of defect is important
  - Some defects may be tolerated
  - Our goal is typically acceptable reliability, not correctness
- May be subjective or objective - for instance, usability, generic level of maintainability or portability
  - How might we make usability objective?
- Even implicit qualities should be verified
  - Because requirements are often incomplete
  - For instance robustness, maintainability, performance
- What is better than implicitly specified qualities?

Approaches to Verification

- What are some approaches to verification?
- How can we categorize these approaches?

Approaches to Verification

- Experiment with behaviour of product
  - Sample behaviours via testing
  - Goal is to find "counter examples"
  - Dynamic technique
  - Examples: unit testing, integration testing, acceptance testing, white box testing, stress testing, etc.
- Analyze product to deduce its adequacy
  - Analytic study of properties
  - Static technique
  - Examples: Code walk-throughs, code inspections, correctness proof, etc.

Does our Engineering Analogy Fail?

- If a bridge can hold 512 kN, can it hold 499 kN?
- If our software works for the input 512, will it work for 499?

Verification in Engineering

- Example of bridge design
- One test assures infinite correct situations
- In software a small change in the input may result in significantly different behaviour
- There are also chaotic systems in nature, but products of engineering design are usually stable and well-behaved