Lecture 15: Verification and Validation

Refresher: definitions of V&V

V&V strategies

Independent V&V

Quality Assurance

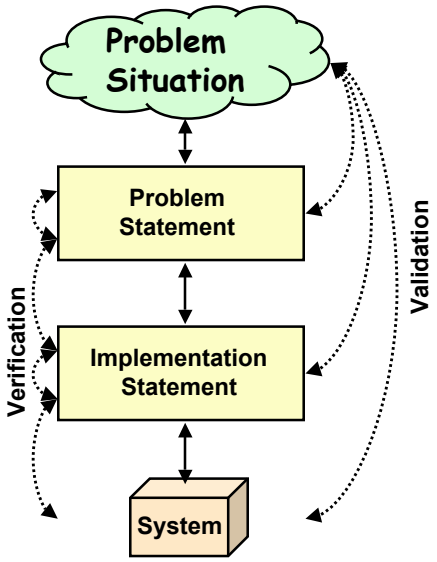
Refresher: V&V

Validation:

- "Are we building the right system?"
- Does our problem statement accurately capture the real problem?
- Did we account for the needs of all the stakeholders?

Verification:

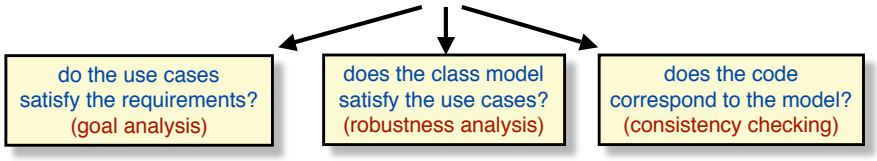
- "Are we building the system right?"
- Does our design meet the spec?
- Does our implementation meet the spec?
- Does the delivered system do what we said it would do?
- Are our requirements models consistent with one another?



Verification

Traditional approaches to verification

Model-based Verification



Basic Cross-Checks for UML

Use Case Diagrams

- Does each use case have a user?
  - Does each user have at least one use case?
- Is each use case documented?
  - Using sequence diagrams or equivalent

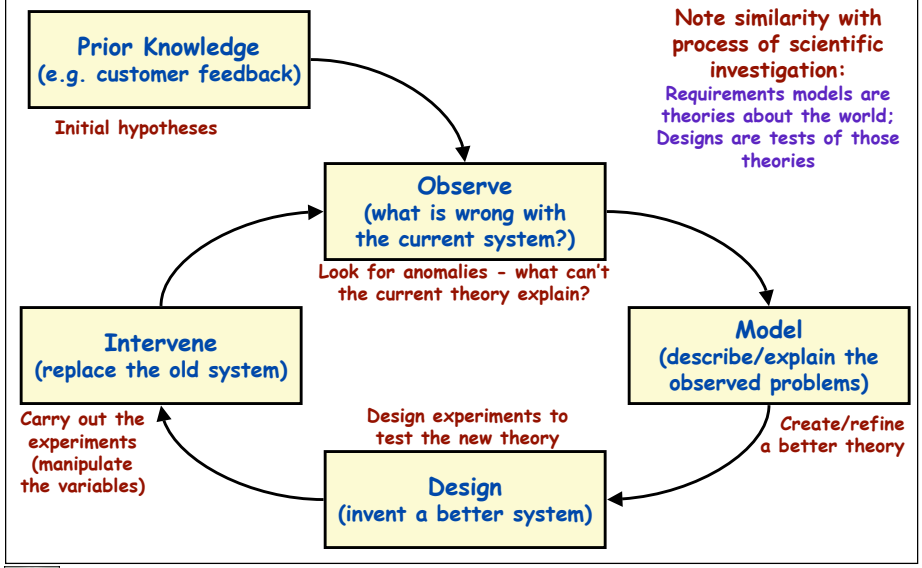
Class Diagrams

- Does the class diagram capture all the classes mentioned in other diagrams?
- Does every class have methods to get/set its attributes?

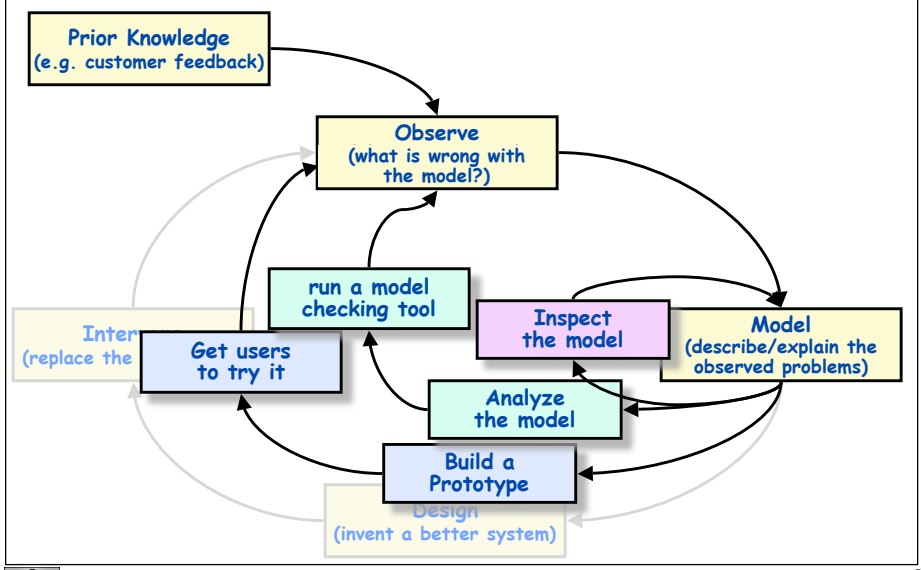
Sequence Diagrams

- Is each class in the class diagram?
- Can each message be sent?
  - Is there an association connecting sender and receiver classes on the class diagram?
  - Is there a method call in the sending class for each sent message?
  - Is there a method call in the receiving class for each received message?

Understanding Validation



Validation techniques



Prototyping

Presentation Prototypes

explain, demonstrate and inform – then throw away
e.g. used for proof of concept; explaining design features; etc.

Exploratory Prototypes

used to determine problems, elicit needs, clarify goals, compare design options
informal, unstructured and thrown away.

Breadboards or Experimental Prototypes

explore technical feasibility; test suitability of a technology
Typically no user/customer involvement

Evolutionary

(e.g. "operational prototypes", "pilot systems"):
development seen as continuous process of adapting the system
"prototype" is an early deliverable, to be continually improved.

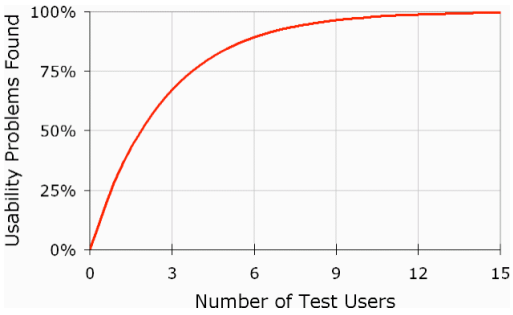
Usability Testing

Real users try out the system (or prototype)

Choose representative tasks
Choose representative users
Observe what problems they encounter

How many users?

3-5 users gives best return on investment



Model Analysis

Verification

- "Is the model well-formed?"
- Are the parts of the model consistent with one another?

Validation:

- Animation of the model on small examples
- Formal challenges:
  - "if the model is correct then the following property should hold..."
- 'What if' questions:
  - reasoning about the consequences of particular requirements;
  - reasoning about the effect of possible changes
  - "will the system ever do the following..."
- State exploration
  - E.g. use model checking to find traces that satisfy some property

Model Checkers

Checks properties expressed in Temporal Logic

- temporal logic adds modal operators to FOPL:
- e.g. $\Box p$ - p is true now and always (in the future)
- e.g. $\Diamond p$ - p is true eventually (in the future)
- e.g. $\Box(p \Rightarrow \Diamond q)$ - each p is eventually followed by a q

The model may be:

- of the program itself (each statement is a 'state')
- an abstraction of the program
- a model of the specifications
- a model of the requirements

A Model Checker searches all paths in the state space

- …with lots of techniques for reducing the size of the search
- Model checking does not guarantee correctness…
  - it only tells you about the properties you ask about
  - it may not be able to search the entire state space (too big!)
- …but is (generally) more practical than proofs of correctness.

Inspections…

"Management reviews"

- E.g. preliminary design review (PDR), critical design review (CDR), …
- Used to provide confidence that the design is sound
- Audience: management and sponsors (customers)

"Walkthroughs" = scientific peer review

- developer technique (usually informal)
- used by development teams to improve quality of product
- focus is on understanding design choices and finding defects

"(Fagan) Inspections"

- a process management tool (always formal)
- used to improve quality of the development process
- collect defect data to analyze the quality of the process
- written output is important
- major role in training junior staff and transferring expertise

Why use inspection?

Inspections are very effective

- *Code* inspections are better than testing for finding defects
- For *Specifications*, inspection is all we have (you can't "test" a spec!)

Key ideas:

- Preparation: reviewers inspect individually first
- Collection meeting: reviewers meet to merge their defect lists
- Log each defect, but don't spend time trying to fix it
- The meeting plays an important role:
  - Reviewers learn from one another when they compare their lists
  - Additional defects are uncovered
- Defect profiles from inspection are important for process improvement

Wide choice of inspection techniques:

- What roles to use in the meeting?
- How to structure the meeting?
- What kind of checklist to use?

Structuring the inspection

Checklist

- uses a checklist of questions/issues
- review structured by issue on the list

Walkthough

- one person presents the product step-by-step
- review is structured by the product

Round Robin

- each reviewer in turn gets to raise an issue
- review is structured by the review team

Speed Review

- each reviewer gets 3 minutes to review a chunk, then passes to the next person
- good for assessing comprehensibility!

Benefits of formal inspection

Source: Adapted from Blum, 1992, Freedman and Weinberg, 1990, & notes from Philip Johnson.

For applications programming:

- more effective than testing
- most reviewed programs run correctly first time
- compare: 10-50 attempts for test/debug approach

Data from large projects

- error reduction by a factor of 5; (10 in some reported cases)
- improvement in productivity: 14% to 25%
- percentage of errors found by inspection: 58% to 82%
- cost reduction of 50%-80% for V&V (even including cost of inspection)

Effects on staff competence:

- increased morale, reduced turnover
- better estimation and scheduling (more knowledge about defect profiles)
- better management recognition of staff ability

Role for Independent V&V?

V&V performed by a separate contractor

- Independent V&V fulfills the need for an independent technical opinion.
- Cost between 5% and 15% of development costs
- NASA Studies show up to fivefold return on investment:
  - Errors found earlier, cheaper to fix, cheaper to re-test
  - Clearer specifications
  - Developer more likely to use best practices

Three types of independence:

- Managerial Independence:
  - separate responsibility from that of developing the software
  - can decide when and where to focus the V&V effort
- Financial Independence:
  - Costed and funded separately
  - No risk of diverting resources when the going gets tough
- Technical Independence:
  - Different personnel, to avoid analyst bias
  - Use of different tools and techniques

Quality Assurance

V&V focuses on the quality of the product(s)

- requirements, models, specifications, designs, code,...

QA focuses on the quality of the processes

- How well are the processes documented?
- How well do people follow these processes?
- Does the organisation measure key quality indicators?
- Does the organisation learn from its mistakes?

Examples:

- ISO9001
- TickIt
- Capability Maturity Model (CMM)
- Total Quality Management (TQM)

E.g. CMM

Level	Characteristic	Key Challenges
5. Optimizing	Improvement fed back into process	Identify process indicators "Empower" individuals
4. Managed	(Quantitative) measured process	Automatic collection of process data Use process data to analyze and modify the process
3. Defined	(Qualitative) process defined and institutionalized	Process measurement Process analysis Quantitative Quality Plans
2. Repeatable	(Intuitive) process dependent on individuals	Establish a process group Identify a process architecture Introduce SE methods and tools
1. Initial	Ad hoc / Chaotic No cost estimation, planning, management.	Project Management Project Planning Configuration Mgmnt, Change Control Software Quality Assurance

Arguments against QA

Costs may outweigh the benefits

Costs: Increased documentation; more meetings; …

Benefits: Improved quality of the process outputs (better software?)

Reduced "agility"

Documenting the processes makes them less flexible

Reduced "thinking"

Following the defined process gets in the way of thinking about the best way to do the job

Barrier to Innovation

New ideas have to be incorporated into the Quality Plan and get signed off

Demotivation

Extra bureaucracy makes people frustrated