Lecture 15: Verification and Validation

Refresher: definitions of V&V

V&V strategies

- Modeling and Prototyping
- Inspection
- Formal Analysis
- (Testing)

Independent V&V

Quality Assurance

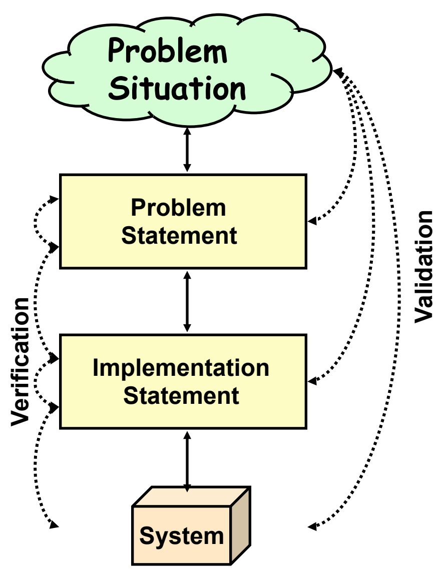
Refresher: V&V

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

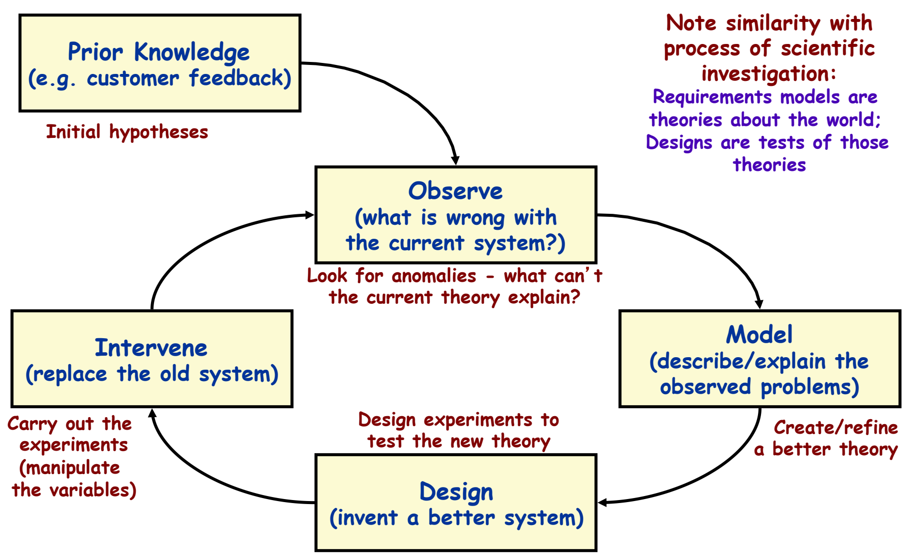
Traditional approaches to (code) verification

- experiment with the program (testing)
- inspect the program (reviews)
- reason about the program (static verification)

Model-based verification

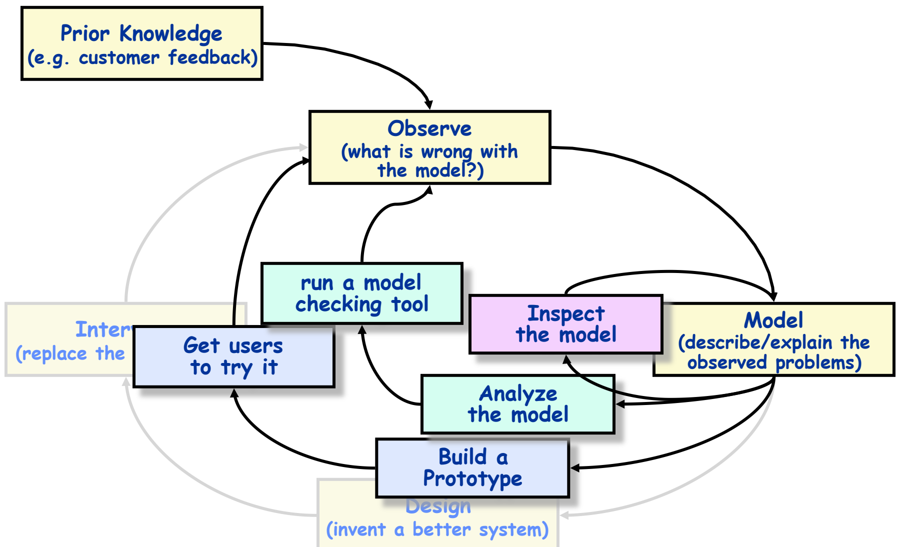
- do the use cases satisfy the requirements? (goal analysis)
- does the class model satisfy the use cases? (robustness analysis)
- does the code correspond to the model? (consistency checking)

Understanding Validation

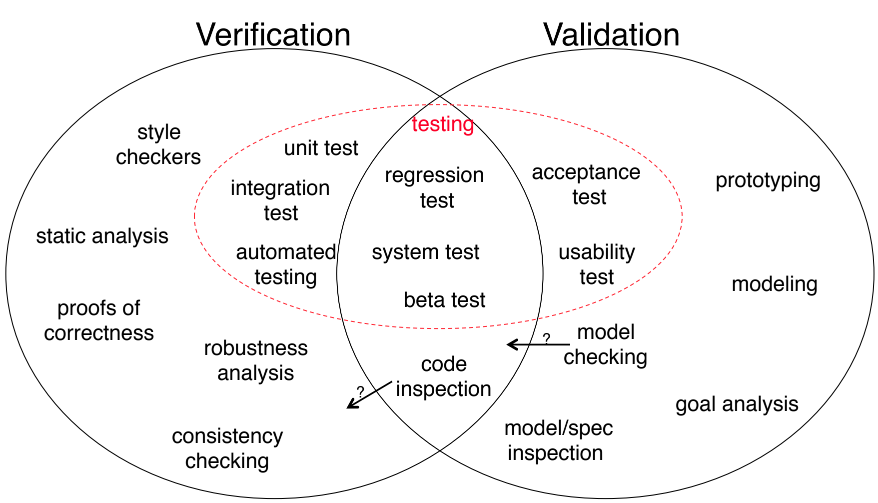


Note similarity with process of scientific investigation:
Requirements models are theories about the world;
Designs are tests of those theories

Validation techniques



Choice of 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, or test suitability of a technology, then thrown away
- Typically no user/customer involvement

Evolutionary
- (a.k.a. "operational prototypes", "pilot systems"):
- Development seen as continuous process of adapting the system
- "prototype" is an early deliverable, to be continually improved.

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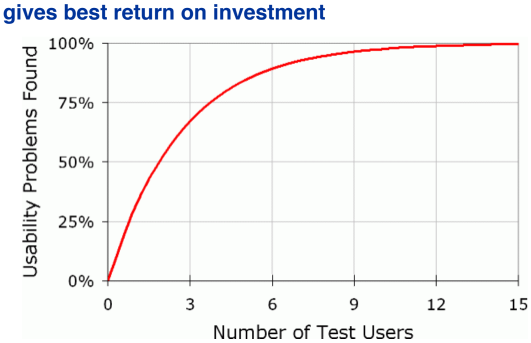
Usability Testing

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



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Model Analysis

Verification

“Is the model well-formed?”

Are the parts of the model consistent with one another?

Validation:

‘What if’ questions:
- reasoning about the consequences of particular requirements;
- reasoning about the effect of possible changes
- “will the system ever do the following...”

Formal challenges:
- “if the model is correct then the following property should hold...”

Animation of the model on small examples

State exploration
- E.g. use model checking to find traces that satisfy some property

UML Consistency Checking

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?

Model Checkers

Automatically check properties (expressed in Temporal Logic)

- temporal logic adds modal operators to FOPL:
  - □p p is true now and always (in the future)
  - ◇p p is true eventually (in the future)
  - □(p⇒◇q) whenever p occurs, it's always (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 specification
- 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 good at finding many safety, liveness and concurrency problems

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 *Models* and *Specs*, it ensures domain experts carefully review them

Key ideas:

- Preparation: reviewers inspect individually first
- Collection meeting: reviewers meet to merge their defect lists
- Note 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