Lecture 10, Part 1: Verification and Validation

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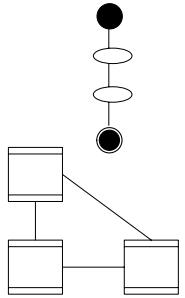
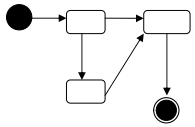
CSC340 - Winter 2007

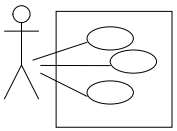
UML Models

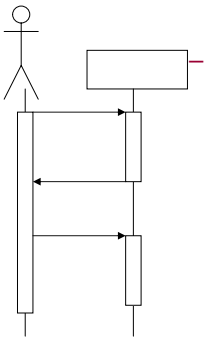




- **Activity diagrams**
  - capture business processes involving concurrency and synchronization
  - good for analyzing dependencies between tasks
- **Class Diagrams**
  - capture the structure of the information used by the system
  - good for analysing the relationships between data items used by the system
  - good for helping you identify a modular structure for the system
- **Statecharts**
  - capture all possible responses of an object to all uses cases in which it is involved
  - good for modeling the dynamic behavior of a class of objects
  - good for analyzing event ordering, reachability, deadlock, etc.

UML Models [2]





- **Use Cases**
  - capture the view of the system from the view of its users
  - good starting point for specification of functionality
  - good visual overview of the main functional requirements
- **Sequence Diagrams**
  - capture an individual scenario (one path through a use case)
  - good for modelling dialog structure for a user interface or a business process
  - good for identifying which objects (classes) participate in each use case
  - helps confirm that all the necessary classes and operations have been identified

Non-UML models

- **Goal Models**
  - Capture strategic goals of stakeholders
  - Good for exploring ‘how’ and ‘why’ questions with stakeholders
  - Good for analysing trade-offs, especially over design choices
- **Fault Tree Models** (as an example risk analysis technique)
  - Capture potential failures of a system and their root causes
- **Entity-Relationship Models**
  - Capture the relational structure of information to be stored
  - Good for analysing risk, especially in safety-critical applications
  - Good for understanding constraints and assumptions about the subject domain
  - Good basis for database design
- **Mode Class Tables, Event Tables and Condition Tables (SCR)**
  - Capture the dynamic behaviour of a real-time reactive system
  - Good for representing functional mapping of inputs to outputs
  - Good for making behavioural models precise, for automated reasoning

Objectives of V&V

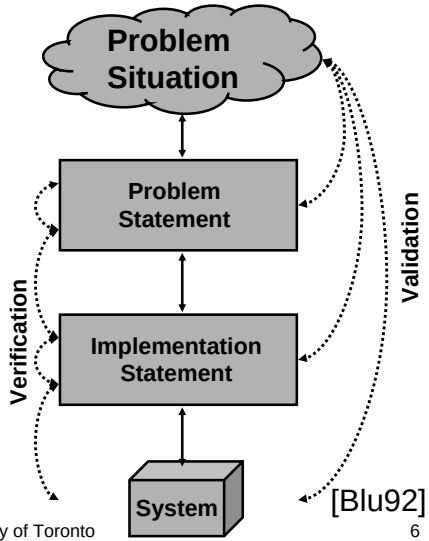
"The overall objective of V&V approaches is to insure that the project is free from failures and meets its user's expectations."

- **Correctness**
  - The product is free of errors.
- **Consistency**
  - The product is consistent (within itself and with other related products).
- **Necessity**
  - Everything in the product is necessary.
- **Sufficiency**
  - The product is complete.
- **Quality**
  - The product satisfies its quality requirements.

[Col88]

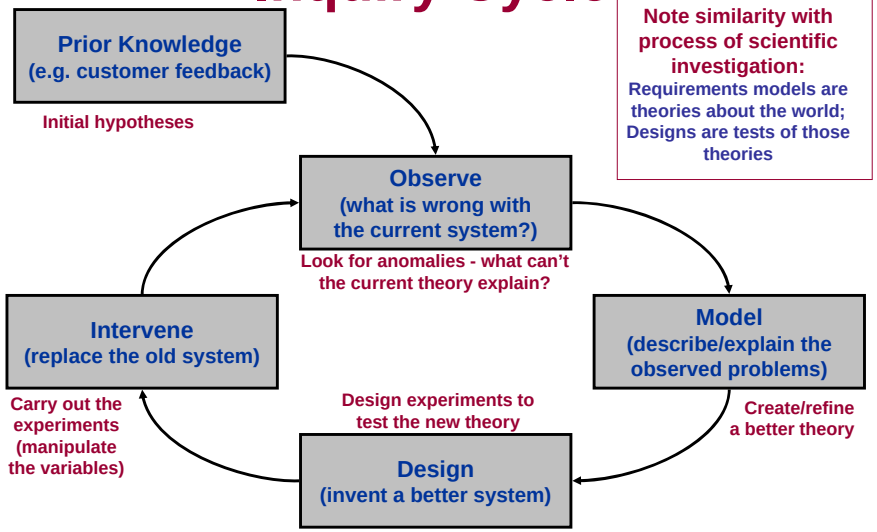
Verification and Validation

- **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?



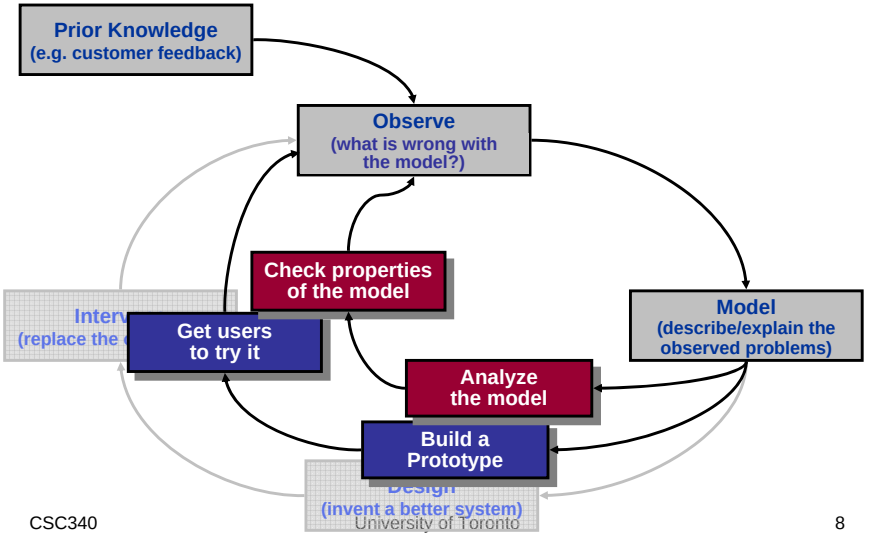
[Blu92]

Inquiry Cycle

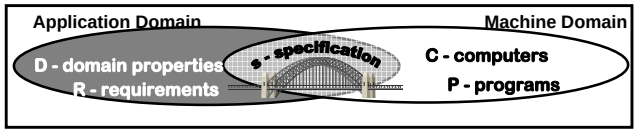


Note similarity with process of scientific investigation:
Requirements models are theories about the world; Designs are tests of those theories

Shortcuts in the inquiry cycle



Refresher: V&V Criteria



[Jac95]

- **Domain Properties**: things in the application domain that are true anyway
- **Requirements**: things in the application domain that we wish to be made true
- **Specification**: a description of the **behaviours** the program must have in order to meet the requirements

- Two verification criteria:
  - The **Program** running on a particular **Computer** satisfies the **Specification**
  - The **Specification**, given the **Domain properties**, satisfies the **Requirements**

- Two validation criteria:
  - Did we discover (and understand) all the important **Requirements**?
  - Did we discover (and understand) all the relevant **Domain properties**?

V&V Example

- **Requirement R**:
  - "Reverse thrust shall only be enabled when the aircraft is moving on the runway"
- **Domain Properties D**:
  - Wheel pulses on if and only if wheels turning
  - Wheels turning if and only if moving on runway
- **Specification S**:
  - Reverse thrust enabled if and only if wheel pulses on
- **Validation**
  - Are our assumptions, D, about the domain correct? Did we miss any?
  - Are the requirements, R, what is really needed? Did we miss any?
- **Verification**
  - Does the flight software, P, running on the aircraft flight computer, C, correctly implement S?
  - Does S, in the context of assumptions D, satisfy R?

V&V Activities

- **Reviews**
  - Walkthroughs, inspections, etc.
- **Software Testing**
  - Not applicable to RE.
- **Formal Methods**
  - Use mathematics to prove that the requirements are consistent.
- **Consistency checking** (this can also be done formally)
  - Verifying consistency between models
- **Prototyping**
  - Present a prototype to the stakeholder to confirm that it has the expected behaviour.
- **Requirements Tracing**
  - Trace each requirement back to its source.

[Col88]

V&V Activities: Reviews

(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

Management reviews
- E.g. preliminary design review (PDR), critical design review (CDR), …
- Used to provide confidence that the requirements are sound
- Attended by management and sponsors (customers)
- Often just a "dog-and-pony show"

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

Review the SRS with stakeholders to validate.

V&V Activities: Formal Methods

Model Analysis

- 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 a model checking to find traces that satisfy some property
- "Is the model well-formed?"
  - Are the parts of the model **consistent** with one another?

V&V Activities: Consistency Checking

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?

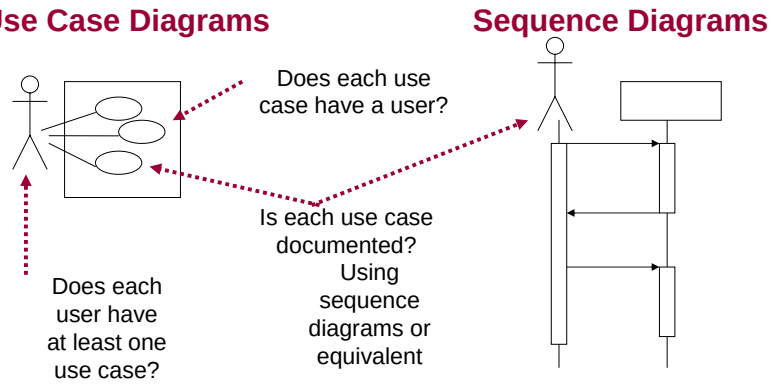
Sequence Diagrams

- 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?

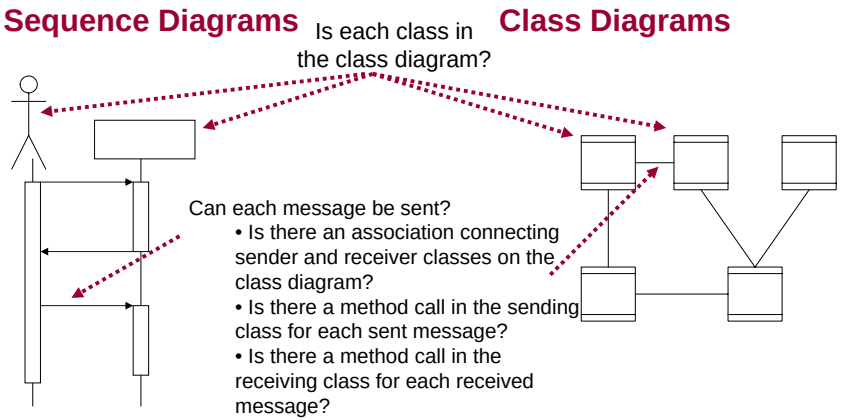
StateChart Diagrams

- Does each statechart diagram capture (the states of) a single class?
  - Is that class in the class diagram?
- Does each transition have a trigger event?
  - Is it clear which object initiates each event?
  - Is each event listed as an operation for that object's class in the class diagram?
- Does each state represent a distinct combination of attribute values?
  - Is it clear which combination of attribute values?
  - Are all those attributes shown on the class diagram?
- Are there method calls in the class diagram for each transition?
  - …a method call that will update attribute values for the new state?
  - …method calls that will test any conditions on the transition?
  - …method calls that will carry out any actions on the transition?

V&V Activities: Consistency Checking [2]



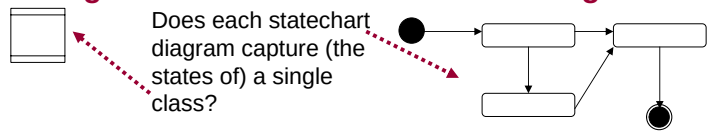
V&V Activities: Consistency Checking [3]



Verification

V&V Activities: Consistency Checking [4]

Class Diagrams **Statechart Diagrams**



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Validation

V&V Activities : Prototyping

"A software prototype is a partial implementation constructed primarily to enable customers, users, or developers to learn more about a problem or its solution."

[Davis 1990]

"Prototyping is the process of building a working model of the system"

[Agresti 1986]

Validation

V&V Activities : Prototyping [2]

Approaches to 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.

Validation

V&V Activities : Prototyping [3]

"Plan to throw one away - you will anyway!", Fred Brooks

Throwaway Prototyping

- **Purpose:**
  - to learn more about the problem or its solution…
  - discard after desired knowledge is gained.
- **Use:**
  - early or late
- **Approach:**
  - horizontal - build only one layer (e.g. UI)
  - "quick and dirty"

Evolutionary Prototyping

- **Purpose**
  - to learn more about the problem or its solution…
  - …and reduce risk by building parts early
- **Use:**
  - incremental; evolutionary
- **Approach:**
  - vertical - partial impl. of all layers;
  - designed to be extended/adapted

V&V Activities : Prototyping [4]

Throwaway Prototyping

- **Advantages:**
  - Learning medium for better convergence
  - Early delivery → early testing → less cost
  - Successful even if it fails!
- **Disadvantages:**
  - Wasted effort if reqts change rapidly
  - Often replaces proper documentation of the requirements
  - May set customers' expectations too high
  - Can get developed into final product

Evolutionary Prototyping

- **Advantages:**
  - Requirements not frozen
  - Return to last increment if error is found
  - Flexible(?)
- **Disadvantages:**
  - Can end up with complex, unstructured system which is hard to maintain
  - early architectural choice may be poor
  - Optimal solutions not guaranteed
  - Lacks control and direction

V&V Activities : Tracing

Forward traceability: trace requirements from stakeholders to requirements specification.

Traceability matrix:

ID	User Requirements	Forward Traceability
S2	Users shall process retirement claims.	R10, R11, R12
S3	Users shall process survivor claims	R13

[Lud05]

V&V Activities : Tracing [2]

Backward traceability: trace requirements from req spec to stakeholder. Traceability matrix:

ID	User Requirements	Backward Traceability
R10	The system shall accept requirement data.	S2
R11	The system shall calculate the amount of retirement.	S2
R12	The system shall calculate point-to-point travel time.	S2
R13	The system shall calculate the amount of survivor annuity.	S3

[Lud05]

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
  - 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

References

[Blu92] Blum, B. I. 1992. *Software engineering: a holistic view*. Oxford University Press.

[Col88] Collofello, J. 1988. *Introduction to Software Verification and Validation*. SEI-CM-12-1.1.

[Jac95] Jackson, Michael. Software Requirements and Specifications. Addison-Wesley, Reading, MA, 1995.

[Lud05] Ludwig Consulting Services. http://www.jiludwig.com/Traceability_Matix_Structure.html