AMSS Lecture 11: Evaluating & Testing UML Models

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2025

Agenda

Goal

Learn how to evaluate, validate, verify, and test UML models using structured techniques and common tools.

General evaluation principles

- Why evaluate UML models?
- Model quality criteria
- Static evaluation techniques
- UML conformance checking

Tools

- Model simulation & execution tools
- Testing scenarios and behavioral models

General Evaluation Principles

Why Evaluate UML Models?

- Models are abstractions $\rightarrow$ may be ambiguous or incomplete
- Early detection of design problems reduces cost
- Ensures consistency across the system architecture
- Supports automated transformations and code generation

Evaluation dimensions

- Consistency
- Completeness
- Correctness
- Usability
- Maintainability

Evaluation dimensions: Consistency

- Ensures uniform use of notation, naming, and style across all UML diagrams.
- Avoids contradictions between different diagram types (e.g., class vs. sequence diagrams).
- Increases clarity and coherence throughout the model.

Evaluation dimensions: Completeness

- All required system elements, behaviors, and interactions are represented.
- No missing components that hinder system understanding.
- Covers all relevant viewpoints needed by stakeholders.

Evaluation dimensions: Correctness

- Follows UML syntax and semantic rules.
- Accurately reflects system requirements and domain constraints.
- Contains no logical, structural, or behavioral errors.

Evaluation dimensions: Usability

- Diagrams are easy for stakeholders to read and interpret.
- Uses an appropriate level of detail—neither too abstract nor too cluttered.
- Supports communication, documentation, and decision-making processes.

Evaluation dimensions: Maintainability

- Diagrams can be easily updated as the system evolves.
- Minimizes unnecessary complexity to accommodate future changes.
- Encourages modular, scalable architecture representation.

UML Model Quality Criteria

Semantic quality

- Are the diagrams logically correct?
- Do they represent valid domain concepts?

Syntactic quality

- Do diagrams follow the UML meta-model?
- Are constructs used properly?

Pragmatic quality

- Are diagrams understandable to stakeholders?
- Are they readable and not over-complex?

Static Evaluation Techniques

- **Checklist-based evaluation**
- **Traceability checks**
- **Cross-diagram consistency checks**

Checklist-based evaluation

Useful for manual reviews.

Typical questions

- Do all classes have well-defined responsibilities?
- Are associations properly navigable?
- Are sequence diagrams consistent with class diagrams?

Benefits

- Improves model quality early, reducing rework during coding.
- Better communication among stakeholders.
- Supports teaching and training for junior modelers.
- Makes model reviews faster and more systematic.

Limitations

- Checklist quality determines quality of evaluation.
  - may miss semantic issues if the checklist is shallow.
- does not replace automated validation tools
  - e.g., UML consistency checkers

Traceability checks

Goal

ensure that every element of a UML model is properly linked to other artifacts across the software lifecycle

- Requirements $\rightarrow$ Use cases $\rightarrow$ Sequence diagrams $\rightarrow$ Classes
- Detect missing or redundant elements

What Do You Check in UML Traceability?

Use Cases – Requirements

- Does every requirement link to at least one use case?
- Does every use case represent a valid requirement?

Use Cases – Interaction Diagrams (Sequence/Communication)

- Are all use case steps represented in a sequence diagram?
- Are alternative flows supported by alternative paths?

Interaction Diagrams – Class Diagrams

- Do all invoked messages map to defined class operations?
- Do lifelines correspond to existing classes?

Class Diagrams – State Machine Diagrams

- Are the state transitions consistent with class operations?
- Do state machines events match interaction diagrams triggers?

Design Models – Test Cases

- Does every use case have at least one test sequence?
- Are all state transitions covered by tests?

Cross-diagram consistency checks

Goal

multiple UML diagrams describing the same system do not contradict one another

- Messages in sequence diagrams correspond to operations in classes
- State diagram transitions match methods/events

Types of Consistency

Syntactic Consistency

- Ensurees diagram elements are used correctly according to UML rules across diagrams.
  - Example: Using the same notation for multiplicity or stereotypes.

Semantic Consistency

- Ensures diagrams describe the same meaning.
  - Example: Sequence diagram says “validateOrder()”, but no such operation exists in the class diagram.

Behavioral Consistency

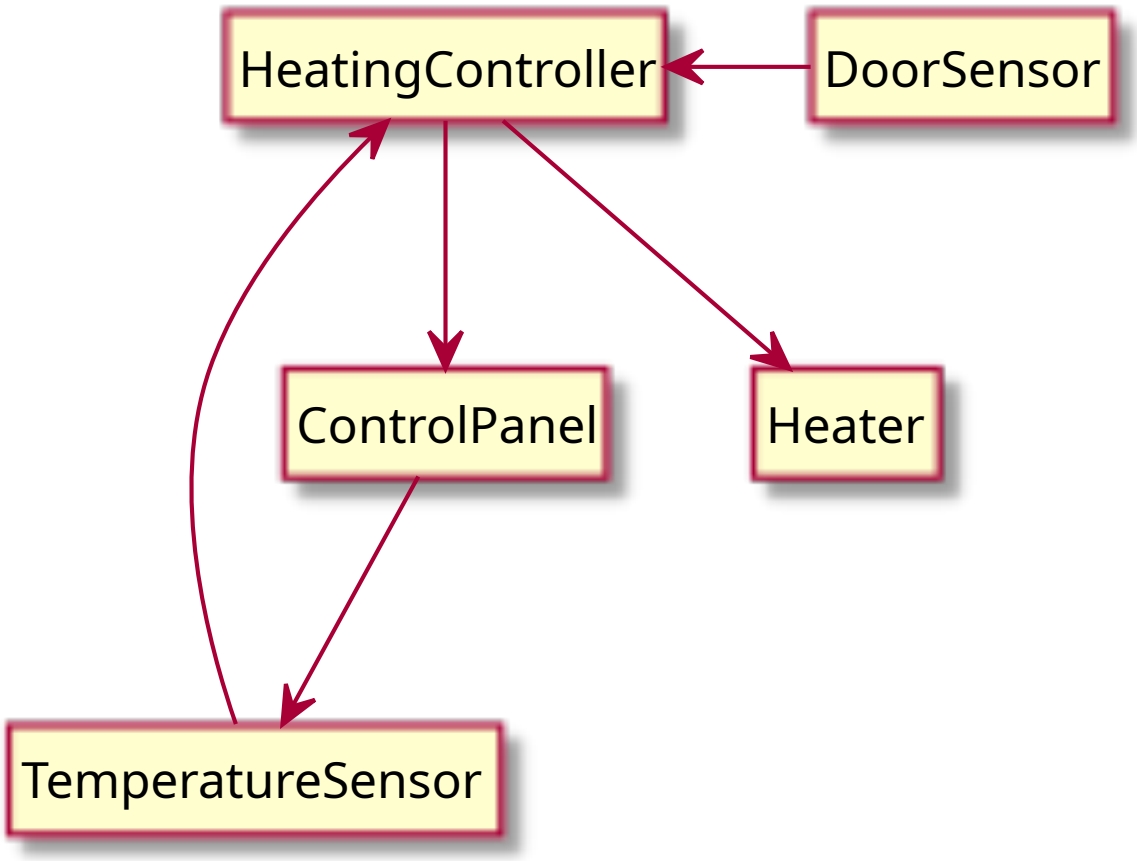
- Ensures system behavior is logically coherent across diagrams.
  - Example: A state transition occurs only if an event is possible in the sequence diagram.

Naming Consistency

- Names of classes, attributes, operations, events, and states must be the same across all diagrams.
  - Example: “CustomerAccount” vs “ClientAccount”.

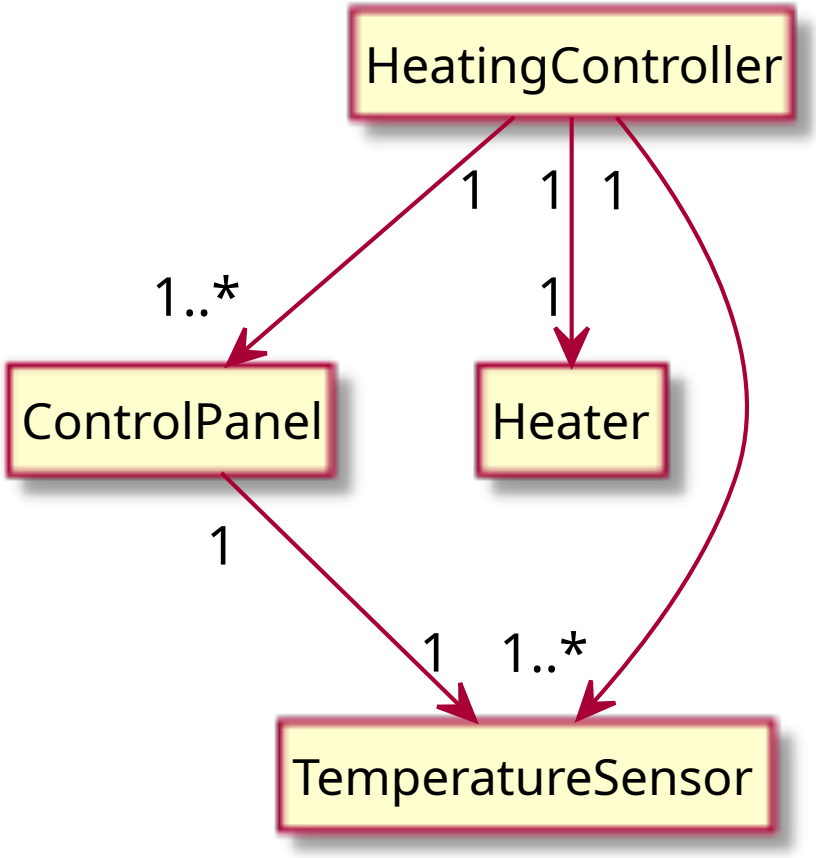
Interactive Exercise

Identify **3 possible inconsistencies** in the following class diagram:



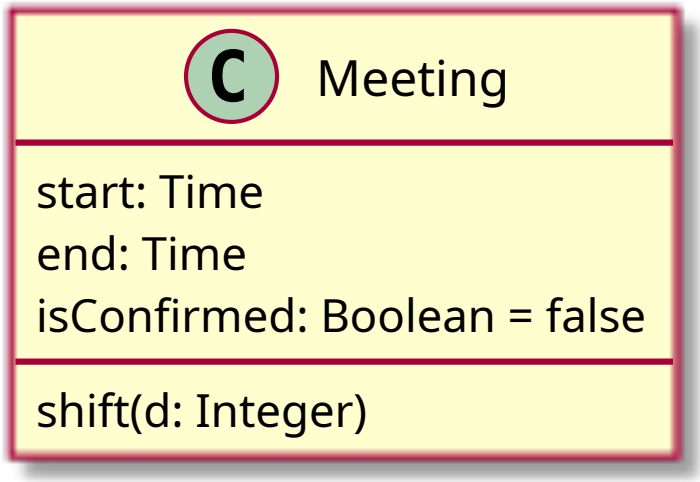
Possible solution

- A `DoorSensor` doesn't logically belong to heating
- `TemperatureSensor - HeatingController` is backwards
- associations are unqualified.



Tools for UML OCL Consistency Checking

Expressing constraints using OCL



- invariants

```
context Meeting inv: end > start
```

- action triggers as pre-conditions

```
context Meeting::shift(d:Integer)
pre: isConfirmed = false and d>0
```

- post conditions

```
context Meeting::shift(d:Integer)
post: start = start@pre + d and end = end@pre + d
```

OCL consistency checking tools

Static analysis

- **USE (UML-based Specification Environment)**
  - research from University of Bremen
  - Executes OCL constraints
  - Generates object diagrams to validate designs

Model validation inside modeling tools

- **Papyrus** (Eclipse-based, supports OCL constraints)
  - research by various French institutions
- **Magic Software Architect** by No Magic, Inc.
  - research from TU Dresden
- **Enterprise Architect** by Sparx Systems

Facilities

- Verify UML meta-model conformance
- Check stereotype/constraint validity
- Detect broken references

Simulation and Execution Tools

Sequence diagram execution

- Animate interactions
- Highlight active lifelines
- Execute state machines

Tools

- **IBM Rhapsody**,
- **Papyrus-RT**,
- **Cameo Simulation Toolkit**

State machine simulation

- Visual debugging of transitions
- Event injection
- Coverage measurement (visited states)

Tools

- Xholon, open source, by Primordion
- Magic Model Analyst
- partially Papyrus Moka

Activity diagram execution

- Token-based simulation
- Deadlock/livelock detection

Tools

- Papyrus Moka
- Magic Model Analyst

Testing Behavioral Models

Model-Based Testing (MBT)

Use the UML model as the basis for generating tests.

- **Sequence diagrams** → Interaction tests
- **State machines** → Transition coverage tests
- **Activity diagrams** → Path tests

Tools (test generation from UML models)

- **Conformiq Designer**
  - originally a start-up based on Finland government-funded research
- **RTT-MBT**
  - by Verified Systems, spin-off from University of Bremen
- **MBT suite**

State-Based Test Example

For a DoorSensor state machine:

- States: `Closed`, `Open`, `Alert`
- Transitions: `doorOpened`, `doorClosed`, `alarmTriggered`

Test coverage:

- Visit all states
- Trigger each transition
- Evaluate guard conditions

Cross-Model Evaluation

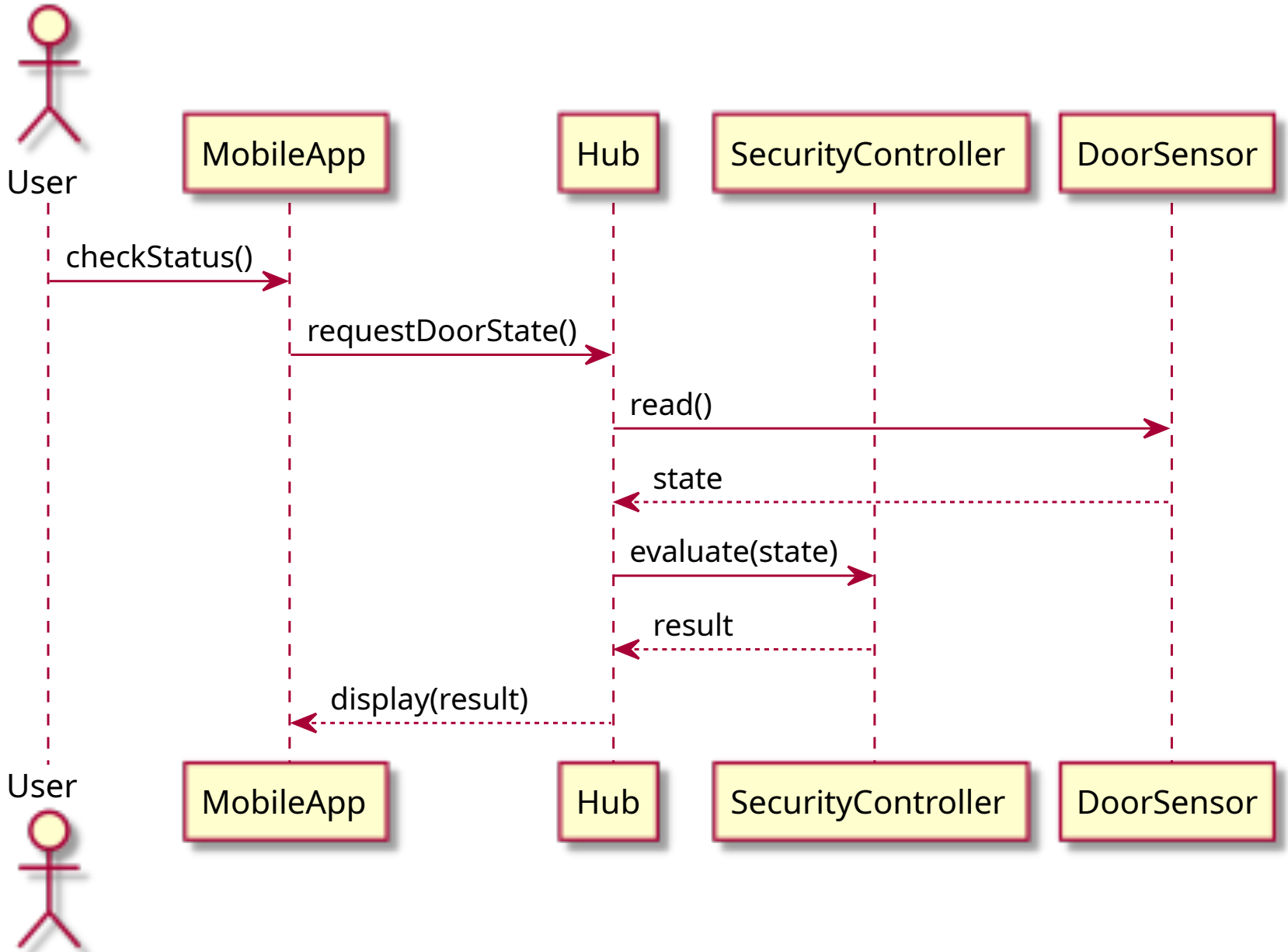
- Every event in a state machine appears in a sequence diagram
- Every lifeline in a sequence diagram corresponds to a class
- Every operation message matches a method signature

Tools supporting this:

- **MagicDraw/Cameo** (robust cross-diagram analyzer)
- **Enterprise Architect** (dependency matrix + traceability)
- **Papyrus** (custom validation rules)

Interactive Exercise

What should happen? What can go wrong? Design test cases.



Wrap-Up

- Evaluating UML models prevents early design flaws
- Tools support: syntax checking, semantic validation, simulation
- Model-Based Testing connects behavioral diagrams with executable tests