Lecture 6: Models

CS 5150, Spring 2025

Administrative reminders

- Assignment A2 released (Due Feb 20)
- Project Plan (Due Feb 11)
  - Schedule meeting with client
  - Share draft for review

Project Scoring Rubrics

- **Client meetings** (at least one per sprint):
  - Participation: Are all members present?
  - Preparation (agenda, clear goals, well-informed questions)
  - Professionalism
- **Presentations**:
  - Mid-point and Final: Content, Organization, Presentation
- **Reports**:
  - Level of details, quality of plan and progress
- **Peer Evaluation**:
  - Professionalism, Initiative, team dynamics, communication, quality

Requirements (Review)

… continued from Lecture 5

Requirements steps

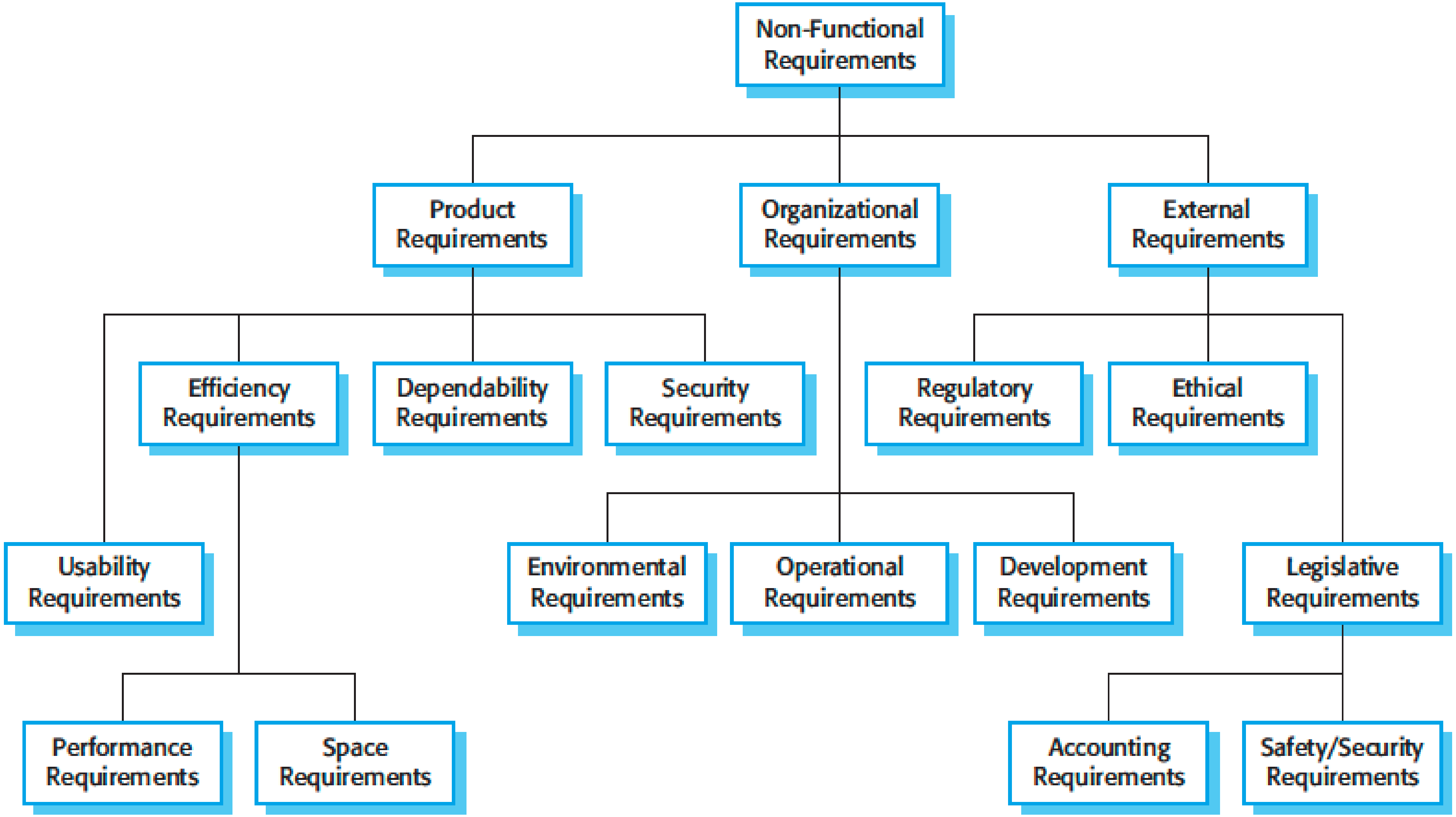
1. Elicitation & analysis
2. Modeling
3. Specification

- Heavyweight
  - Document formal specification before beginning design
- Lightweight
  - Relevant requirements developed during sprints
    - But work out system-level requirements upfront
  - Avoid specification unless necessary
    - Models, prototypes clearer to client
    - Sometimes details are important

Types of Requirements

- **Functional**
  - What a product should do
  - What a product should not do
  - Can be verified locally
- **Non-functional**
  - Aka "quality requirements"
  - Property of system as a whole
- **Constraints**
  - Limits how the system can be built

- Examples:
  - "When a document link is visited, it shall display the document **only if** the user is authorized to read it; otherwise, it shall display a permissions error."
  - "Visual feedback from tapping a control shall be displayed **within 100ms** of contact."
  - "Records of queries issued by users shall be stored in an **Oracle** database."


Non-Functional Requirements
Product Requirements
Organizational Requirements
External Requirements
Efficiency Requirements
Dependability Requirements
Security Requirements
Regulatory Requirements
Ethical Requirements
Usability Requirements
Environmental Requirements
Operational Requirements
Development Requirements
Legislative Requirements
Performance Requirements
Space Requirements
Accounting Requirements
Safety/Security Requirements

Stories & scenarios

- Don’t start with formal specifications
  - Most clients can't relate to them
  - Difficult to evaluate completeness
- **Stories** put devs, client on same wavelength
  - Describe actors and their goals
  - High-level, "big picture"
  - Lavish detail about context
    - Helps crystalize alternative viewpoints
    - Refocus by asking which details are relevant
- **Scenarios** detail interactions with system
  - Agile user stories - narrative scenarios with moderate detail
    - Often written on cards
    - Devs break into tasks to estimate effort
    - Prioritized by clients for inclusion in a sprint
    - Postponed stories may be revised with minimal rework
  - Structured scenarios provide more detail
    - Tool for clarifying requirements, checking completeness

Interviews

- Difficult, but essential
- Tips:
  - Allow plenty of time
  - Prepare before meeting client
  - Keep full notes
  - Clarify what you do not understand
    - Define domain-specific terminology
  - Repeat what you hear
- Consider all stakeholders
- Ask questions
  - "Why do you do things this way?"
  - "Is this essential?"
    - Be wary – impact may not be obvious
  - "What are the alternatives?"

Usage scenarios (or Stories)

- Illustrates some interaction with a proposed system
- Use specific examples from a user's point of view
- Clarifies many functional requirements
- Especially good for analyzing off-nominal behavior

- Must include:
  - Purpose
  - User or transaction being followed
  - Assumptions about equipment
  - Steps of scenario
- Should consider (corner cases)
  - What could go wrong
  - Concurrent activities
  - Changes to system state
- Avoid system details that pertain to design

Poll: What kind of requirement is this?

- “We should migrate all our cloud-based backend services from Azure to AWS”

- A: Functional
- B: Efficiency Requirements
- C: Ethical Requirements
- D: Development Requirements

PollEv.com/cs5150sp25

Lecture goals: Modeling

- Select appropriate models to improve communication during multiple process steps (requirements, architecture, program design)
- Visualize models using UML (Unified Modeling Language)

Models

Purpose of models

- Simplification of reality
- Facilitates communication during process steps
  - Requirements
  - Architecture (system design)
  - Program design
- Need multiple models
  - Different perspectives
  - Different levels of completeness, formality
- Larger, more complex projects benefit from more formality
- Most models are consumed by *humans*

Representing models

- UML: Unified Modeling Language
  - Models consist of diagrams and specifications
  - Many different diagram types
  - Particularly well suited to object-oriented design
- Can serve many purposes
  - Facilitate discussion
  - Provide documentation
  - Generate code

- Why not code?
  - Can have multiple models with simplifications serving different perspectives
  - Code usually must pick a single abstraction; can't manifestly show correctness for other perspectives
  - Code can introduce syntactic distractions, platform details
  - Sometimes, (pseudo)code is the clearest specification

Modeling perspectives

- **External**
  - Represent the (simplified) context of the system wrt environment
- **Interaction**
  - How do user and component interactions proceed?
  - E.g., Use Cases, Sequence Diagrams
- **Structural**
  - How are system components organized?
  - How is data represented? E.g., Class Diagrams
- **Behavioral**
  - How system responds to events, changes over time
  - E.g., Data flow Diagram, State/Transtion Diagrams

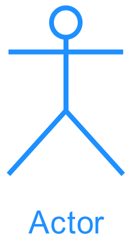
Interaction models

- Modeling user interactions helps catalog functional requirements
  - Use case diagrams

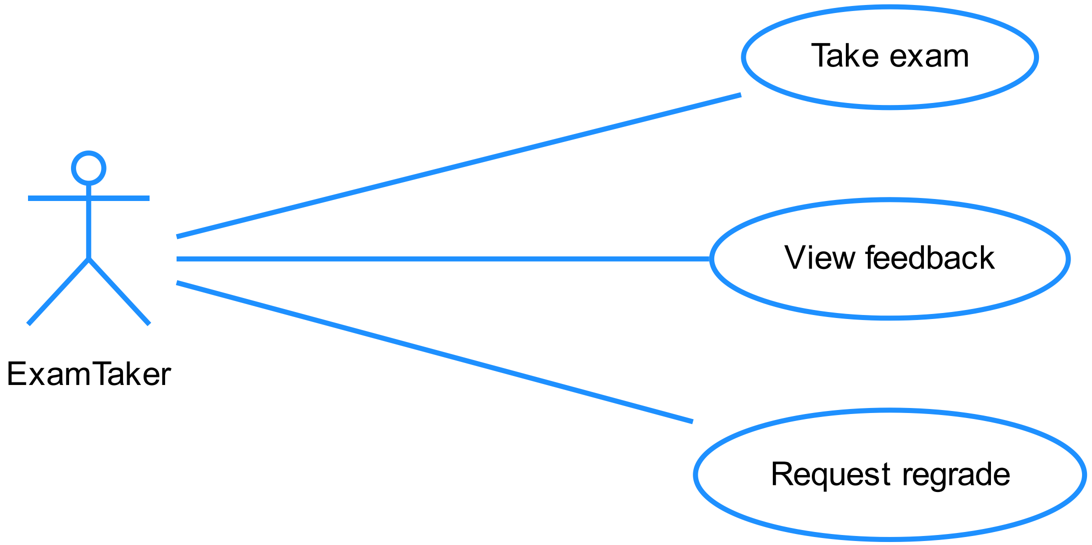
- Modeling inter-system interaction helps highlight potential communication problems
  - Sequence diagrams

Use cases

- Discrete task involving external interaction with the system
- Actor
  - A role, not an individual
  - Beneficiary or instigator
  - May be other systems
  - Use specific, not generic names



- Use case



Pair with textual description

- Metadata
  - Name of use case
  - Goal of use case
  - Actor(s)
  - Trigger
  - Preconditions
  - Postconditions
- Flow of events
  - Basic flow
  - Alternate flows
  - Exceptions

- Name: Take exam
- Goal: Enables a student to take an exam online with a web browser
- Actor(s): ExamTaker
- Trigger: ExamTaker is notified that the exam is ready to be taken
- Preconditions: ExamTaker is registered for course; ExamTaker has authentication credentials
- Postconditions: Completed exam is ready to be graded

Basic flow ("Take exam" use case)

1. ExamTaker connects to server via web browser
2. Server checks whether ExamTaker is already authenticated; if not, triggers authentication process
3. ExamTaker **selects** an exam from list
4. ExamTaker repeatedly selects a question and either types in a new solution, edits an existing solution, or uploads a file with a solution
5. ExamTaker either **submits** exam or **saves** current state
6. When exam is **submitted**, server checks that all questions have been attempted and sends acknowledgement to ExamTaker

Discuss

- What could be some alternate or erroneous scenarios for the “Take Exam” use case?

Alternative flows

Alternate flow

- Alternative path to successful completion of use case

- Example: Take exam
  - Resuming exam from saved state
  - Solution file format not accepted
  - Submission is incomplete

Exceptions

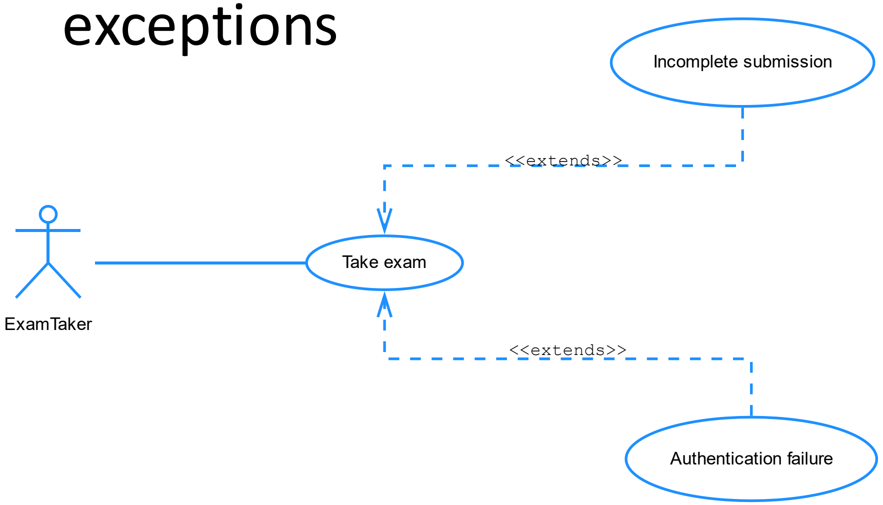
- Lead to failure of use case

- Example: Take exam
  - Authentication failure

Relationships

<<extends>>

- Defer extra detail to other use cases
  - Useful for alternate flows and exceptions



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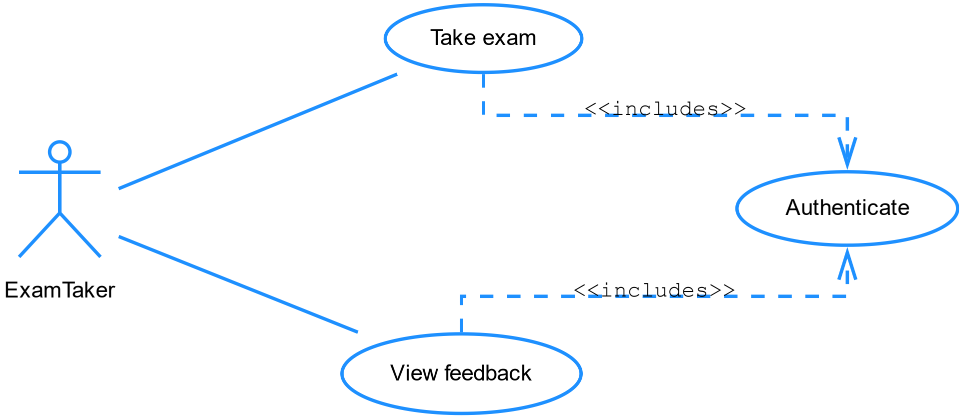
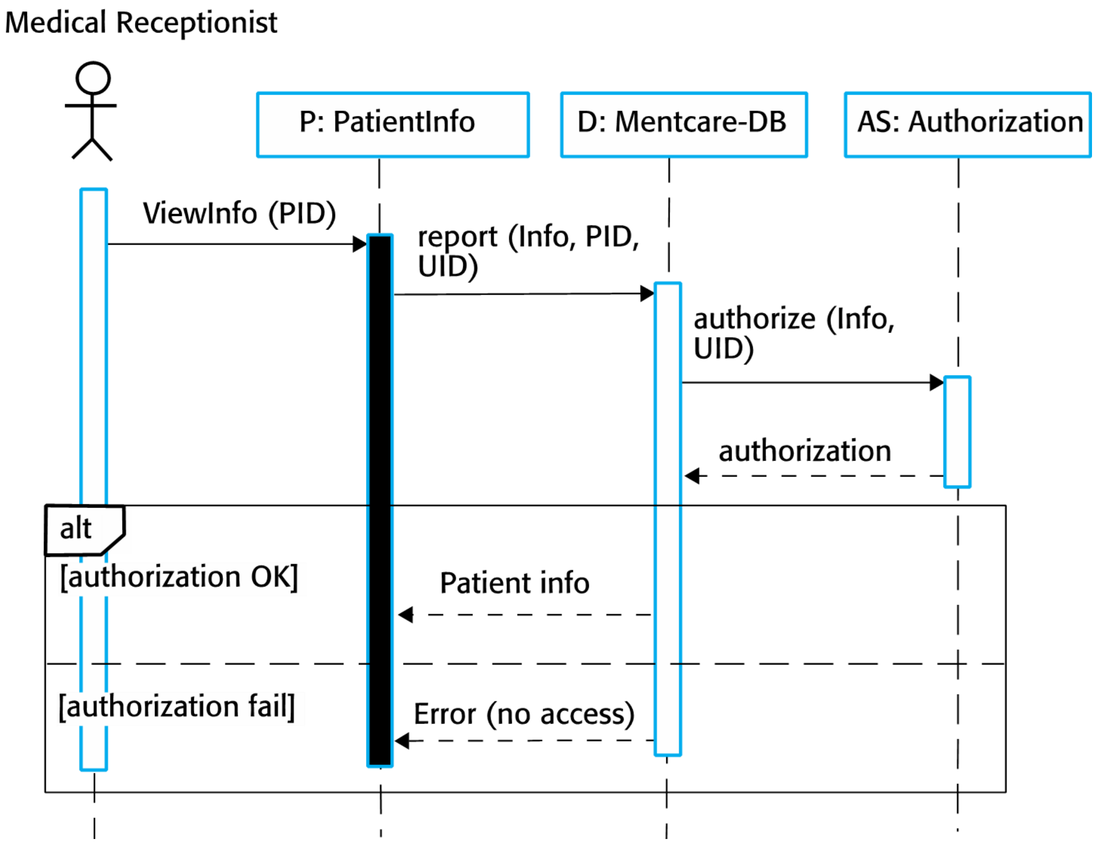
- Include steps from another use case
  - Useful when common procedure is required in multiple contexts



Sequence Diagrams

- Show sequence of interactions (ordering, causal relationships) between actors and objects
  - Excellent for documenting communication protocols
- Networking examples: https://www.eventhelix.com/networking



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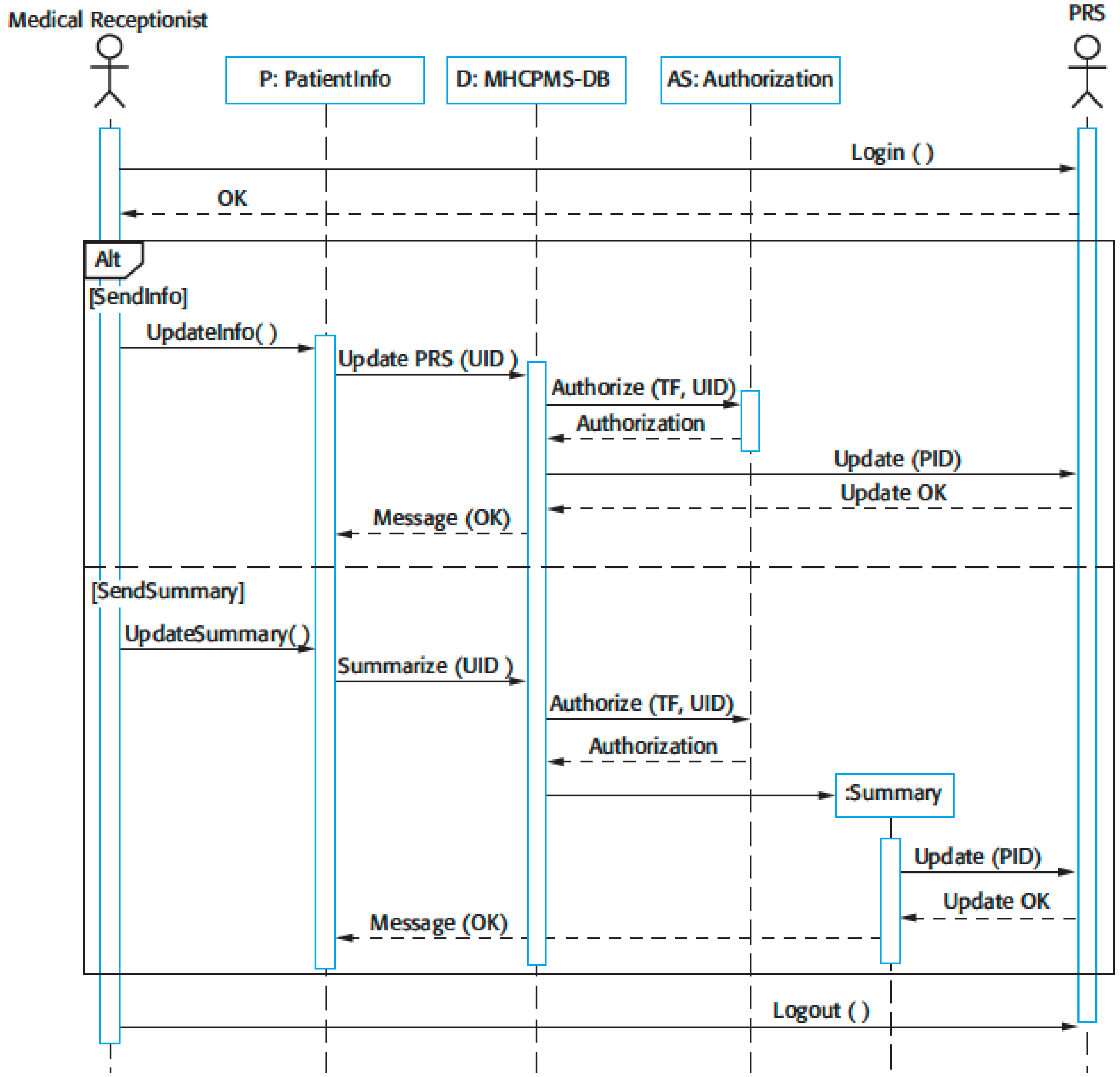
Sequence Diagrams

- A more complex example
- Can be used for code generation



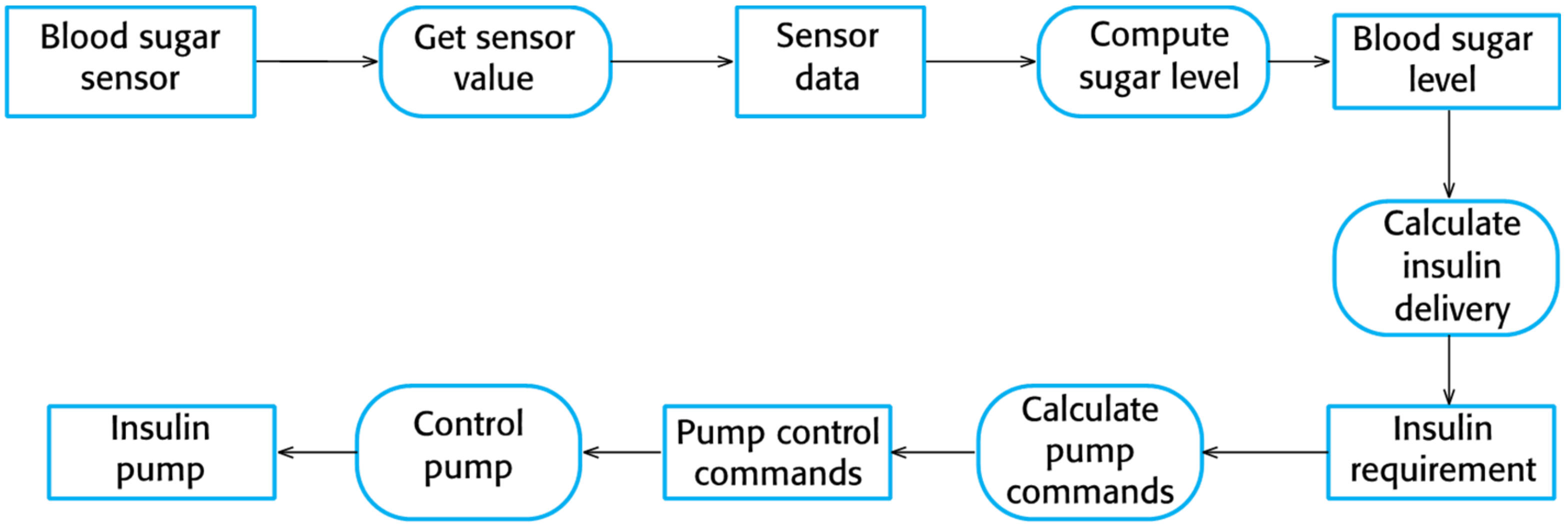
Behavioral Models

- Model dynamic behavior of system during execution
- How does system process data or respond to events?

- Data-driven models
  - Show sequence of processing steps from input to output
- Event-driven models
  - How does system respond to events? (internal and external)
  - Assumes finite number of application states
  - Great for embedded, real-time systems

Data flow (activity) diagrams

- **Example Task**: Chain of Processing in insulin pump software
- **Activity**: rounded rectangle
- **Data**: rectangle or labeled edge
- **Data source/sink**: rectangle
- **Beginning/end**: circle



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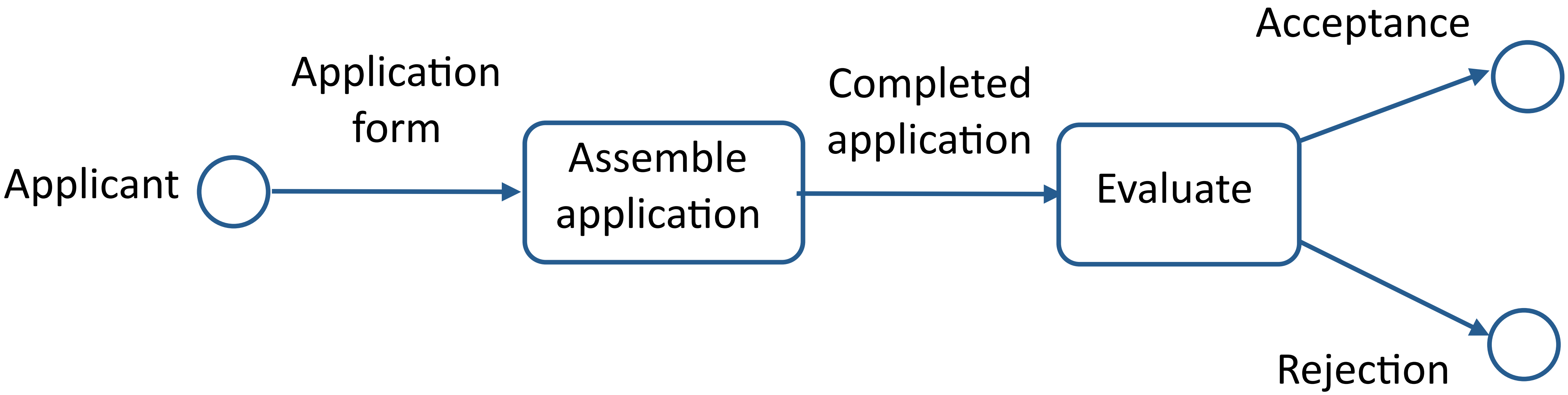
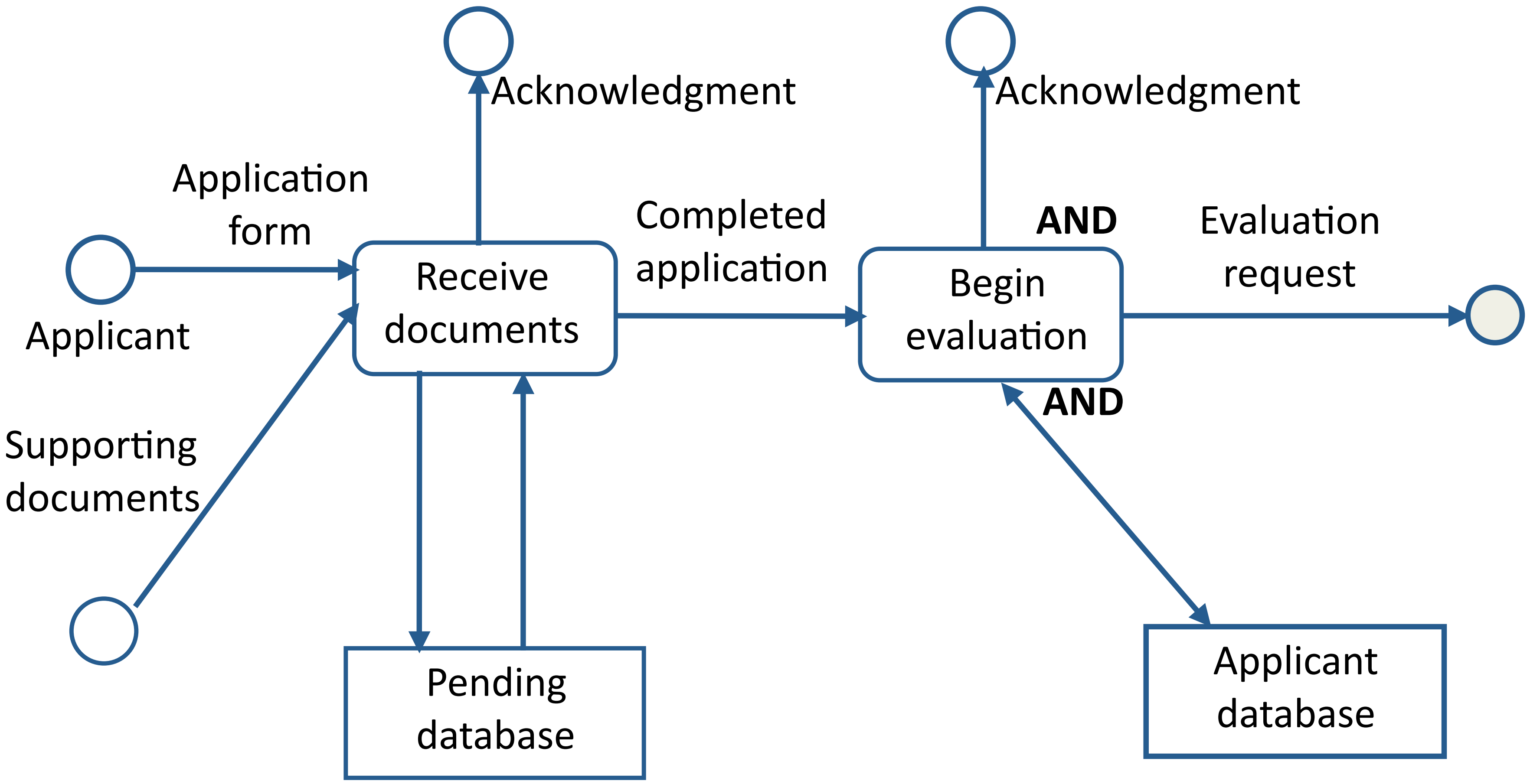
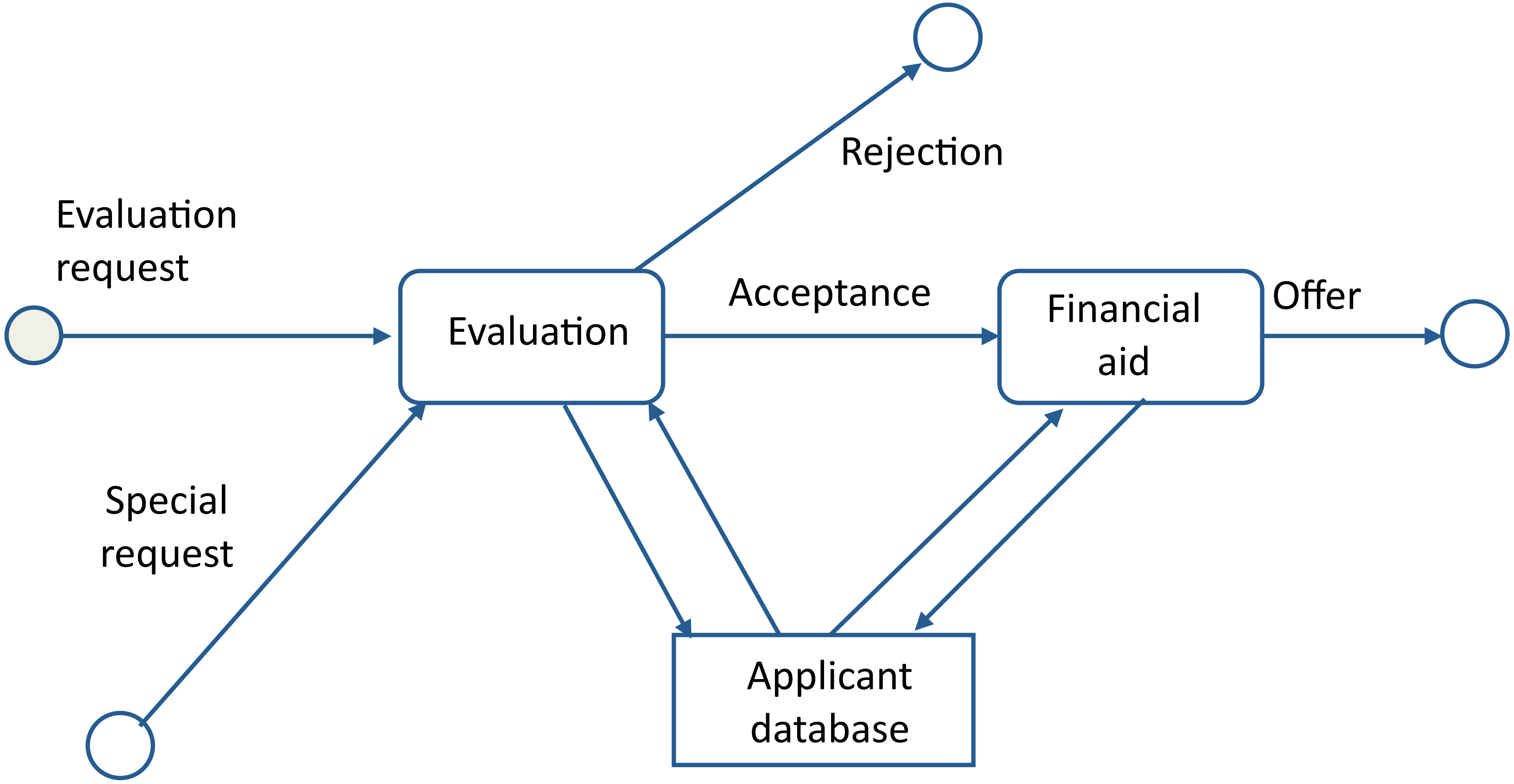
Example: University Admissions



Refined example



Refined example, continued



How to specify logic?

- Data flow & sequence diagrams show high-level flow; must be augmented by specifications for low-level behavior

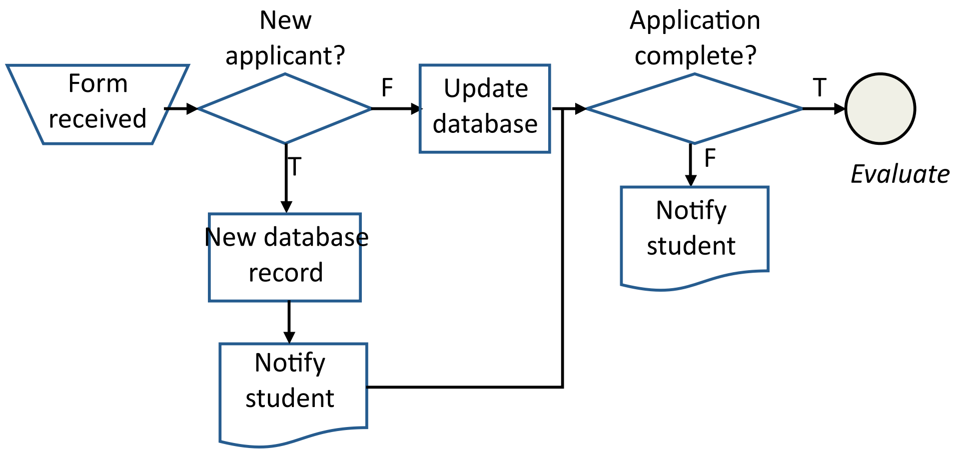
- Decision table
  - Process columns from left to right
  - Rules are specific and testable
  - Can be clearer to clients than code

SAT > S1	T	F	F	F	F	F
GPA > G1	-	T	F	F	F	F
SAT between S1 and S2	-	-	T	T	F	F
GPA between G1 and G2	-	-	T	F	T	F
Accept	*X*	*X*	*X*			
Reject				*X*	*X*	*X*

Flowcharts and pseudocode

Flowchart

- Shows logic (not just flow)
- Used to specify computer programs before modern programming languages



Pseudocode

- Compact and precise
- Composable
- Easy to implement
- Harder to see flow

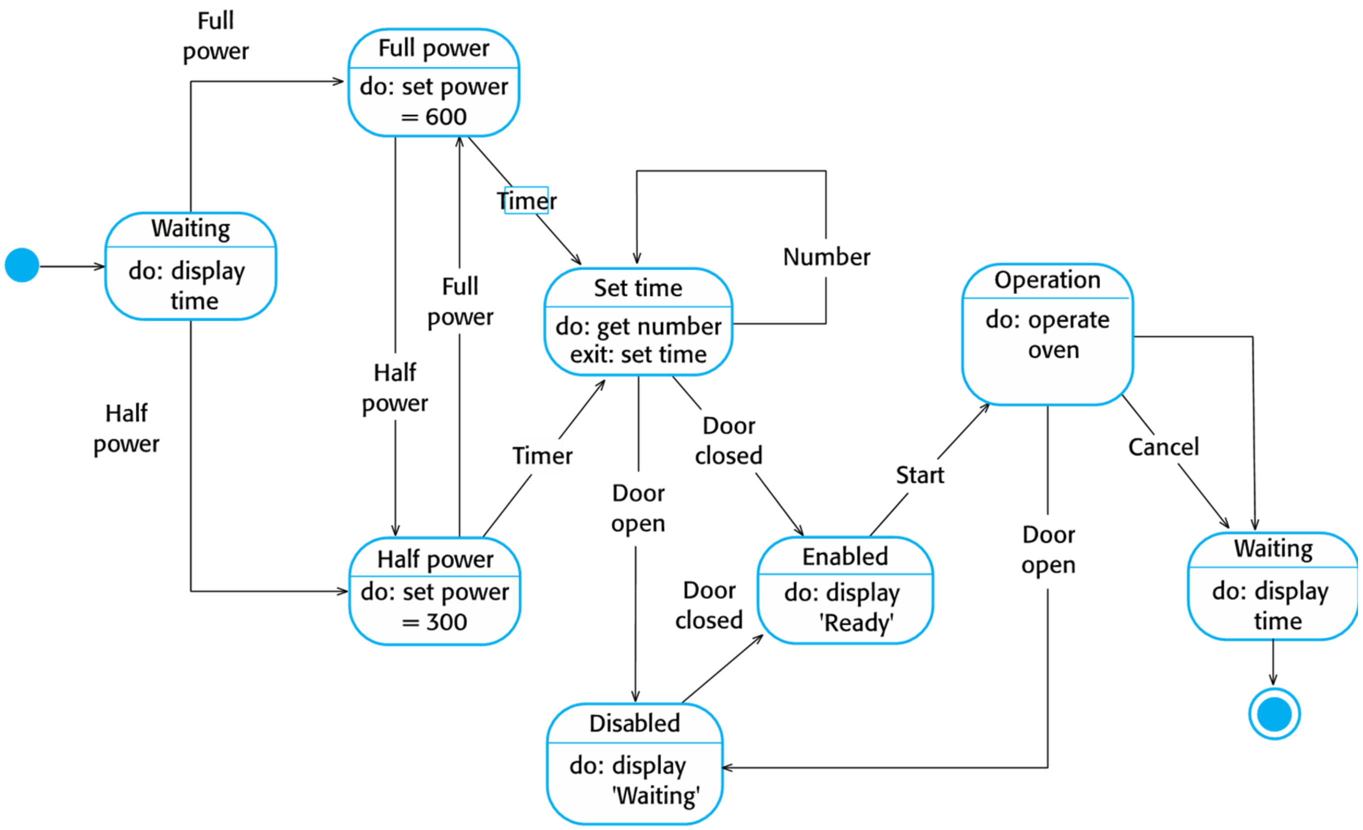
```
admin_decision (application)
    if application.SAT == null then error (incomplete)
    if application.SAT > S1 then accept(application)
    else if application.GPA > G1 then accept(application)
    else if application.SAT > S2 and application.GPA > G2
        then accept(application)
    else reject(application)
```

Mathematics

- Many systems are well-described by mathematical models
  - Differential equations
  - Probability distributions
  - Integrals
  - Filters
  - Interpolation
  - Curve fits
- Document progression of approximations and domain transformations
  - Frequency vs. time domain
  - Continuous vs. discrete
    - Differential vs. difference equations
    - Integration vs. quadrature
    - Root solve vs. Iteration
- Higher-level specifications give developers more flexibility, can improve maintainability

State charts / Transition diagrams (Event Driven Modeling)

- Model system as a finite set of states
- A transition moves the system from one state to another
  - Triggered by a condition
  - Mathematically, a function from $S \times C \to S$
- Can be hierarchical
- Also useful for user interface navigation



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Transition tables

- Specify state transitions in textual form
  - Useful when transitions are "dense" (most conditions are applicable in most states)
  - Example: physical buttons on embedded device
- Can visually check for completeness

State	Next State				
Action>	**Half Power**	**Full Power**	**Timer**	**Door Open**	**Door Close**
Waiting	Half Power	Full Power			
Full Power	Half Power		Set Time		
Half Power			Set Time		
…					

Reminders

- Try to use what you learned in this and previous classes in your project plans
- Projects: Debug issues early
- A2: Debug issues early

- Waitlist/No Team: Please contact me