Design

CSC 326

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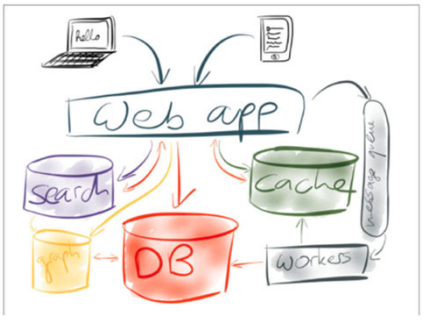
1

Imaging you have an idea about software design, what will you do (to share with you teammate)?

You draw!



2

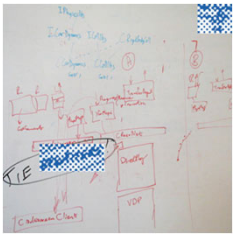
Why Study Design Notation?

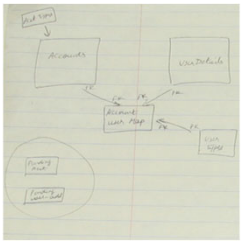
- Drawing and diagramming is essential task in software development

Understanding existing code
Design review
Explain to external members

Ad-hoc meetings (whiteboard)
Onboarding
Hallway art

Refactoring plans
Explain to secondary members
Documentation







"Let's go to the whiteboard: how and why software developers use drawings" **CHI'07** http://research.microsoft.com/pubs/74243/p557-cherubini.pdf

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Types of Diagrams

Interface Design
- Wireframes
- Flow Maps/Navigation Maps

Software Design
- Class Diagrams
- Sequence Diagrams
- State Diagrams

…

Many more specialized types



Specific diagram types [edit]

A
- Activity diagram used in UML 6/9 and SysML

B
- Bachman diagram
- Booch – used in software engineering
- Block diagram
- Block Definition Diagram (BDD) used in SysML
- Business & IT Diagram (B&IT) – used in business and IT modelling

C
- Carroll diagram
- Cartogram
- Category theory diagrams
- Cause-and-effect diagram
- Circuit diagram
- Class diagram – from UML 1/9
- Collaboration diagram – from UML 2.0
- Communication diagram – from UML 2.0
- Commutative diagram
- Component diagram – from UML 3/9
- Composite structure diagram – from UML 2.0
- Concept map
- Constellation diagram
- Context diagram
- Control flow diagram
- Contour diagram
- Cordier diagram
- Cross functional flowchart

D
- Data model diagram
- Data flow diagram
- Data structure diagram
- Dendrogram
- Dependency diagram
- Deployment diagram – from UML 9/9
- Dot and cross diagram
- Double bubble map – used in education
- Drakon-chart

E
- Entity-Relationship diagram (ERD)
- Event-driven process chain
- Euler diagram
- Eye diagram – a diagram of a received telecommunications signal
- Express-G
- Extended Functional Flow Block Diagram (EFFBD)

F
- Family tree
- Feynman diagram
- Flow chart
- Flow process chart
- Fusion diagram

L
- Ladder diagram
- Line of balance
- Link grammar diagram

M
- Martin ERD
- Message Sequence Chart
- Mind map – used for learning, brainstorming, memory, visual thinking and problem solving

N
- N2
- Nassi–Shneiderman diagram or structogram – a representation for structured programming
- Nomogram
- [Network connection]

O
- Object diagram – from UML 2/9

P
- Package diagram from UML 4/9 and SysML
- Parametric diagram from SysML
- PERT
- Petri net – shows the structure of a distributed system as a directed bipartite graph with annotations
- Phylogenetic tree - represents a phylogeny (evolutionary relationships among groups of organisms)
- Piping and instrumentation diagram (P&ID)
- Phase diagram used to present solid/liquid/gas information
- Plant Diagram
- Pressure volume diagram used to analyse engines
- Pourbaix diagram
- Process flow diagram or PFD – used in chemical engineering
- Program structure diagram

R
- Radar chart
- Radial Diagram
- Requirement Diagram Used in SysML
- Rich Picture
- R-diagram

S
- Sankey diagram – represents material, energy or cost flows with quantity proportional arrows in a process network.
- Sentence diagram – represents the grammatical structure of a natural language sentence.
- Sequence diagram from UML 8/9 and SysML
- SDL/GR diagram – Specification and Description Language. SDL is a formal language used in computer science.
- Smith chart
- Spider chart

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Unified Modeling Language

A general-purpose visual modeling language that is intended to provide a standard way to visualize the design of a system.

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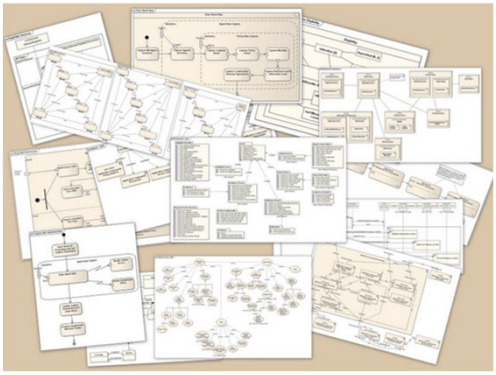
UML - Unified Modeling Language

- UML 2.5 (the latest version)
  - A large graphical design language for modeling object-oriented software.
  - Resulted from the convergence of notations from three leading object-oriented methods:
    - Object-Modeling Technique (OMT)
    - Object-Oriented Software Engineering (OOSE)
    - Object-Oriented Software Development (Booch, authored by Grady Booch)



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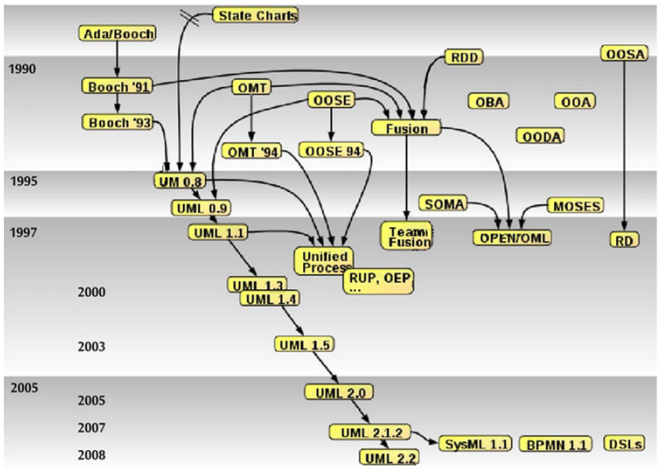
A brief history of UML



https://en.wikipedia.org/wiki/Unified_Modeling_Language#/media/File:OO_Modeling_languages_history.jpg

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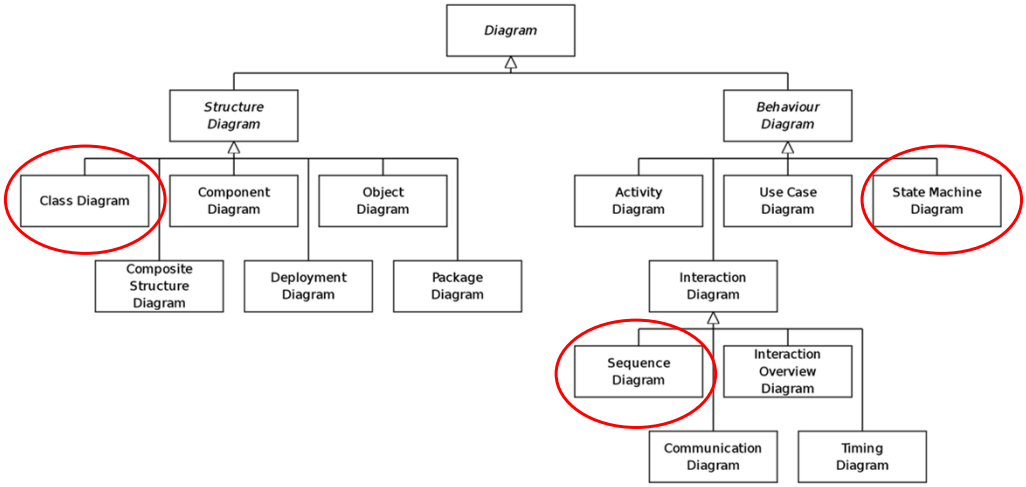
Types of Diagrams by UML



https://en.wikipedia.org/wiki/File:UML_diagrams_overview.svg

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Class Diagrams

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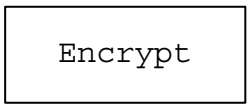
What is a UML *Class* Diagram?

- It is a developer's view of the significant classes in a design
  - We can highlight what we consider important about a class
  - Other information about a class can be omitted from the diagram
- The simplest representation of a class is a box with the name of the class
  - Example: Class Encrypt



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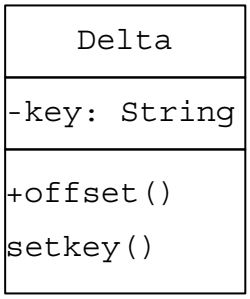
A Class with Attributes and Operations

- More generally, a class representation may show:
  - The class name is required
  - Attributes are like data fields
  - Operations or methods
- Only significant attributes and operations are shown



class name

attributes

operations

11

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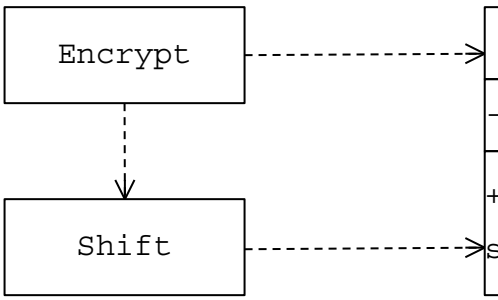
A UML Class Diagram

The dashed arrows show dependencies; e.g., `Encrypt` depends on `Shift`



class name

attributes

operations

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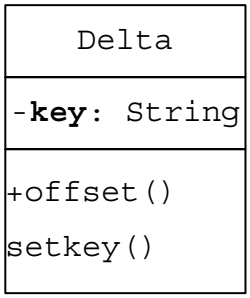
UML is a Modeling Language



- If a class models a real-world entity
  - An attribute models a meaningful property of the entity
- Example: Class `Delta` is a **key** manager in an encryption system
  - Attribute `key` models an encryption key
- Attributes and operations can be made public or kept private
  - Class diagrams can therefore include private implementation details

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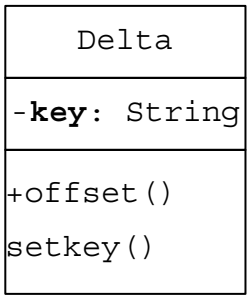
Writing Class Properties as Attributes



- An attribute description has the following elements:
  - Visibility: + for public, - for private
  - Name: Only the name is required
  - Type
  - Multiplicity is about the number of objects represented by an attribute
  - Default value
- If specified, elements appear in the above order

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Writing Attributes Within Class Diagrams

Only the name is required

- Write the name and the type
  - `center : Point`
- Add a default value
  - `center : Point = origin`
- Write the name and the visibility (public)
  - `+center`

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Multiplicity of Objects Represented by an Attribute

- A class may model at least one and possibly many objects
  - Example: Class `Student` models many students
  - Example: Class `Parser` models one syntax analyzer in a compiler
- Multiplicity specifies a range for the number of objects for an attribute
  - [*] one or more
  - [m..n] where m>=0 and n>=m
  - [n] abbreviation for 1..n

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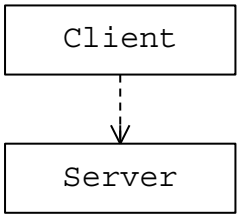
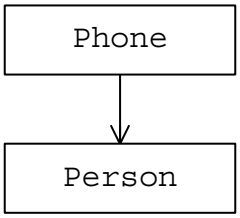
Relationships Between Classes

Note the different kinds of arrows and arrowheads



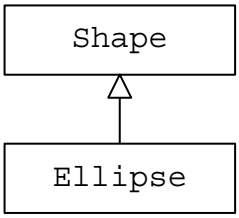
(a) Dependency

(*client depends on server. Server does not depend on client.*)



(b) Association

(each phone *belongs to / is associated with a person*)



(c) Generalization

(An Ellipse *is a type of Shape. A Shape is a generalization of an Ellipse.*)

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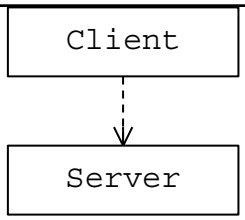
Class Dependencies



- A dependency is represented by a dashed arrow from the dependent class
  - The most common form of dependency is caller-callee or client-server
  - Dependencies can be through any form of coupling
- Example:
  - In a Publish-Subscribe architecture, the publisher raises events
  - The subscribers watch for events
  - The subscribers depend on the publisher, but they do not call it

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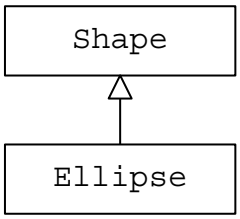
Class Generalization (Subclass-Superclass)

- A generalization is represented by an unfilled triangular arrowhead
  - The arrow is from the subclass to the superclass



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Class Properties as Associations

- UML provides two ways of modeling class properties
  - As attributes, written as lines of text within the box for the class
  - As associations, represented by an open arrow to the property
- How to choose between the two?
  - Use attributes when the property is relevant primarily to the given class
  - Use an association when the property has significance of its own

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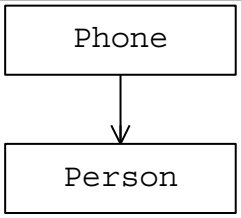
Showing Associations



- Associations can be bidirectional
  - Example: A student takes courses and courses have students
  - Bidirectional associations can be shown with arrows at both ends of a line
  - Alternatively, use a line without arrowheads at either end
- Associations can be named
  - Use verbs as names for readability
  - Example: The name "takes" for the association from student to course
  - Write the name next to the from class, or use a triangle to show direction

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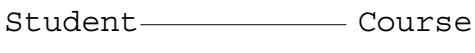
Ways of Writing Associations



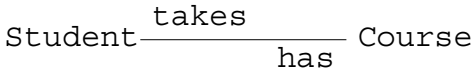
(a) Bidirectional association



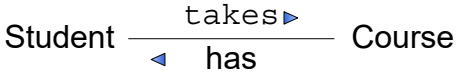
(b) Bidirectional association



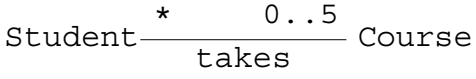
(c) Multiplicities at both ends



(d) Roles for both classes



(e) Verbs for names



(f) Role and multiplicities

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Aggregation vs. Composition Whole-Part Relationship

- Aggregation: stronger association (unidirectional)
  - Whole-Part relationship, where the part can exist separate from the whole
  - Ex. A dept contains a set of employees
  - Ex. A faculty contains a set of teachers
  - A white diamond at the end of the association next to the aggregate class
- Composition: stronger aggregation (unidirectional)
  - Whole-Part relationship, where the whole controls the lifecycle of the part
  - Ex. Invoice–InvoiceLine
  - A black diamond on the end of association next to the composite class

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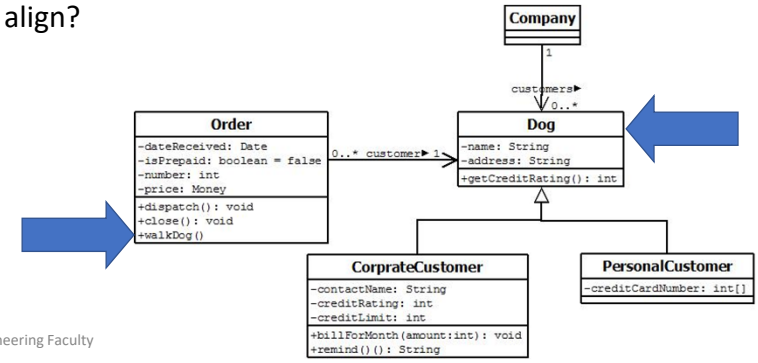
Evaluating a Class/Class Diagram

1. Intention-revealing naming: Does the name of the object convey its abstractions? Does the abstraction have a natural meaning and use in the domain?
2. Single Responsibility: Do the name, main responsibility statement data and functions align?



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Entity-Relationship Diagrams

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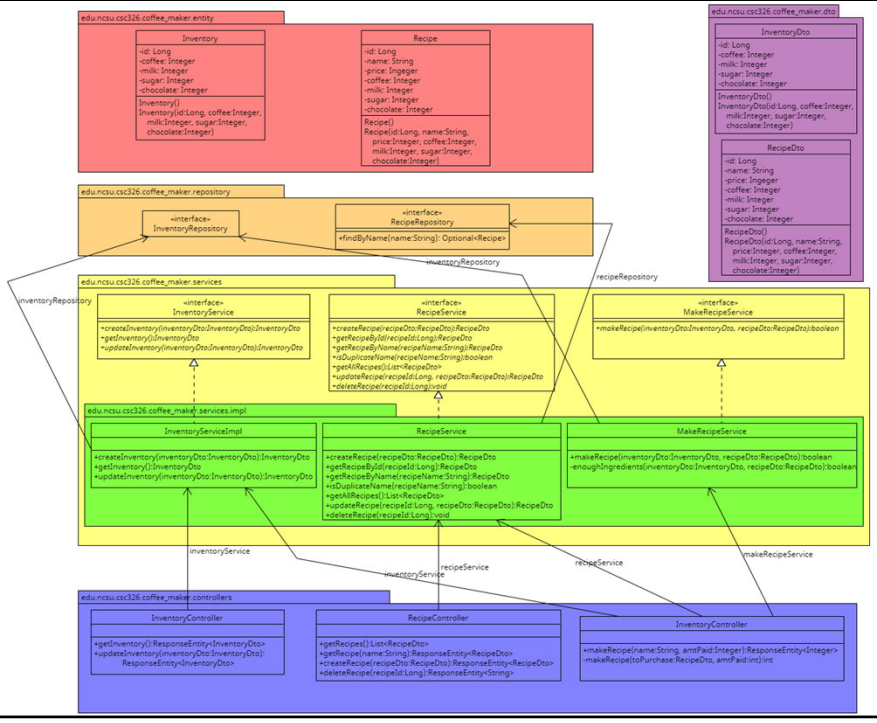
CoffeeMaker Backend Class Diagram (Initial Requirements)



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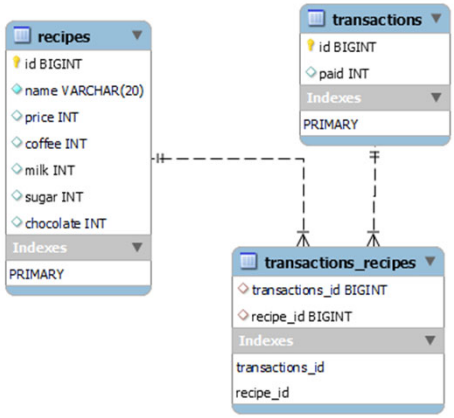
Entity-Relationship (ER) Diagrams

- Relational databases can be modeled using Entity-Relationship (ER) Diagrams
  - Tables show attributes and other important information.
  - Connectors show relationships:
    - These connectors show a 1 to many relationship
- You can create these diagrams in MySQL Workbench (or reverse engineer them)
- Since we are using an ORM, the class diagram provides a description of the data in the database, but ER diagrams provide additional context, particularly around joins.



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Sequence Diagrams

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Sequence Diagrams

- A sequence diagram shows communication between run-time components
  - Objects and processes are examples of components
- Time flows top down
  - Each component is represented by a vertical line
  - The line is topped by a box with the name of the component
- A message to B is modeled by a horizontal arrow from A's line to B's line

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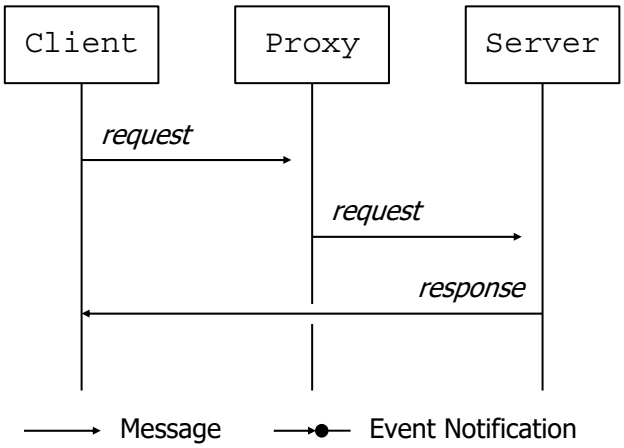
A Sequence Diagram

The client's request is forwarded by the proxy



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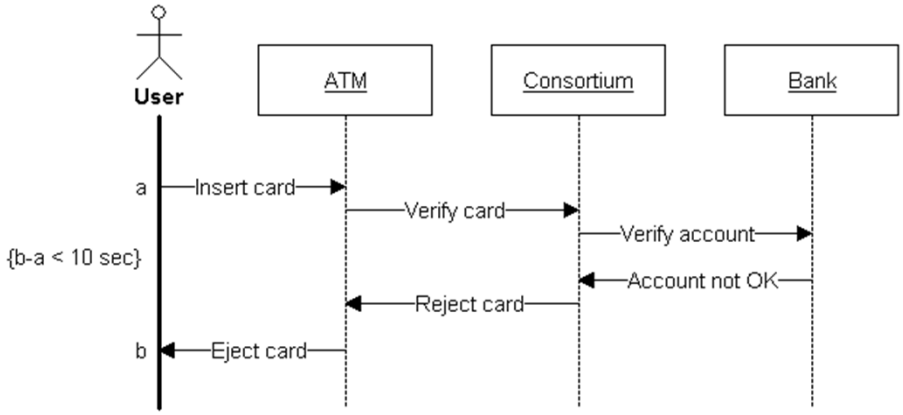
Scenario - withdraw cash



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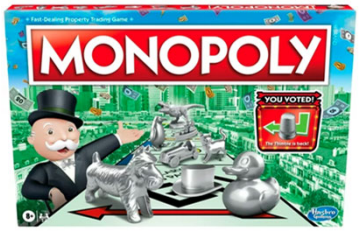
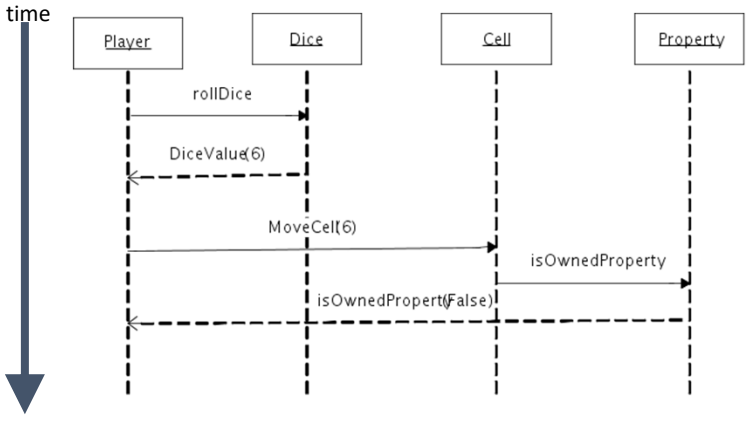
Scenario - Monopoly

A player rolls the dice and gets a 6. The player moves 6 cells. The player lands on a cell that is an un-owned property. The player's turn is over.





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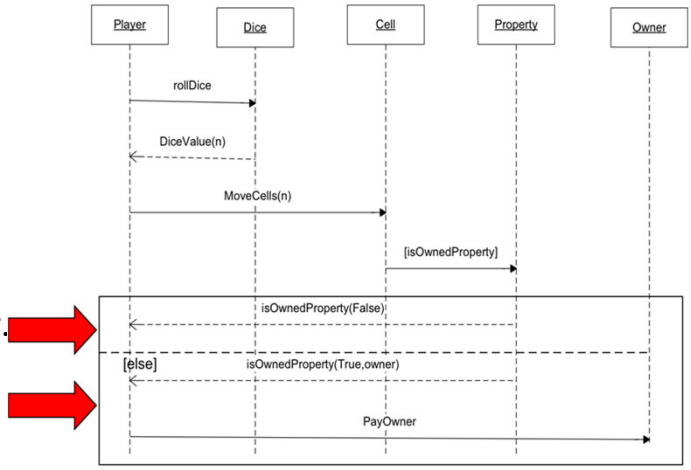
Conditional Logic

- If the player lands on a cell that is unowned property, the player's turn is over
- If the player lands on a cell that is owned, the player must pay rent to the owner of the property
- Then the player's turn is over.



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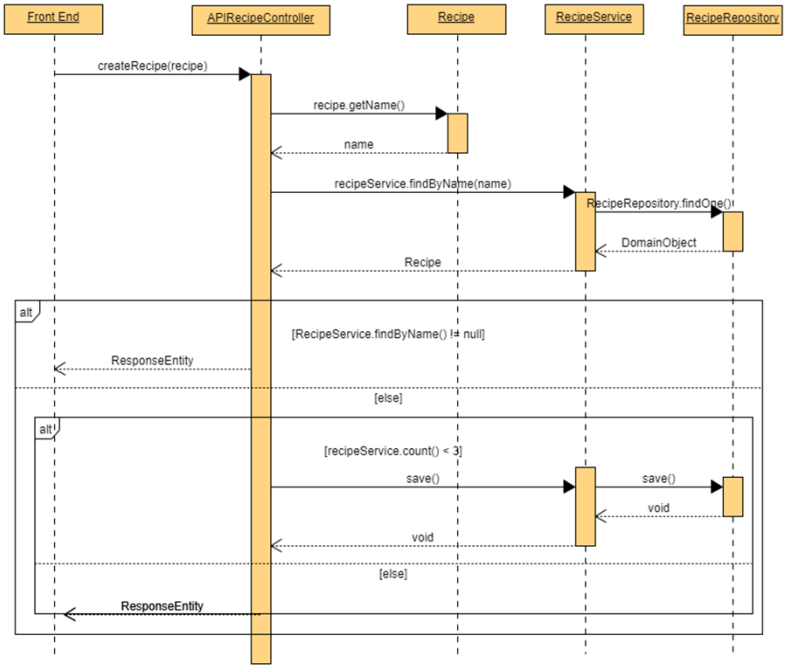
Example from old version of CoffeeMaker



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Uses

- (obvious, formal) Designing flow of information through a system
- (less obvious, less formal use) Debugging a complex system
- (pragmatic) Figuring out what to test
  - Hint: be sure to cover each arrow! These are integration points!

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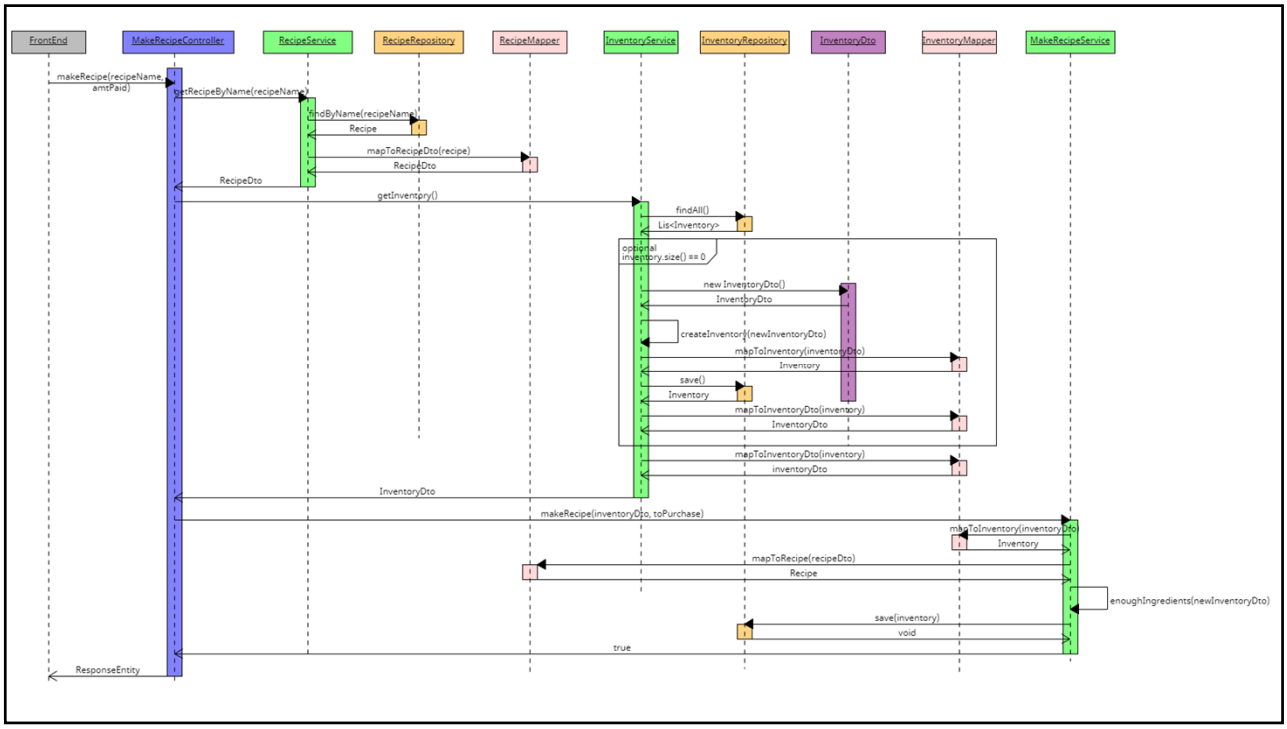

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State Diagrams

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State Diagrams

- A state diagram (also called a state machine diagram) depicts the various states that an object may be in and the transitions between those states.
- Appropriate to be developed for complex objects.

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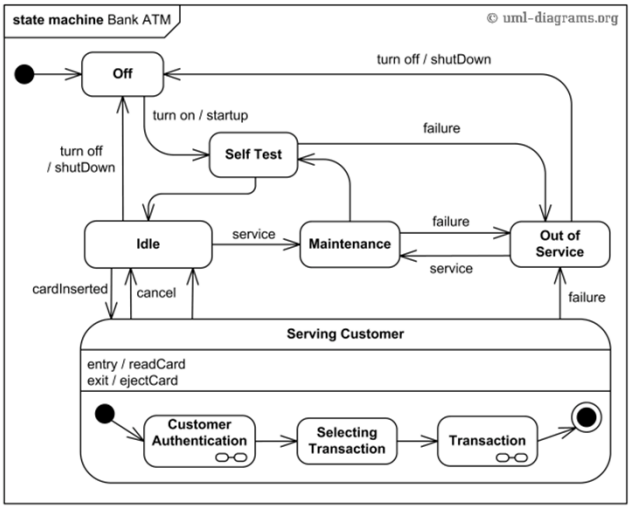
ATM Example



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Transitions

- Transitions are the result of the invocation of a method that causes an important change in state
- Each transition has a label that comes in three parts. All the parts are optional.

trigger-signature [guard] / activity

candle removed [door closed] / reveal lock

- The *trigger-signature* is usually a single event that triggers a potential change of state.
  - Missing trigger-signature [rare] – you take the transition immediately.
- The *guard*, if present, is a Boolean condition that must be true for the transition to be taken.
  - Missing guard – always take the transition.
- The *activity* is some behavior that's "executed" during the transition.
  - Missing activity – don't do anything during the transition.

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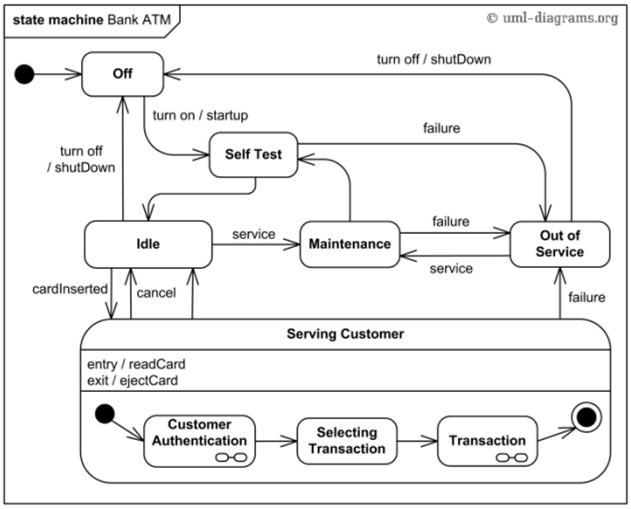
ATM Example



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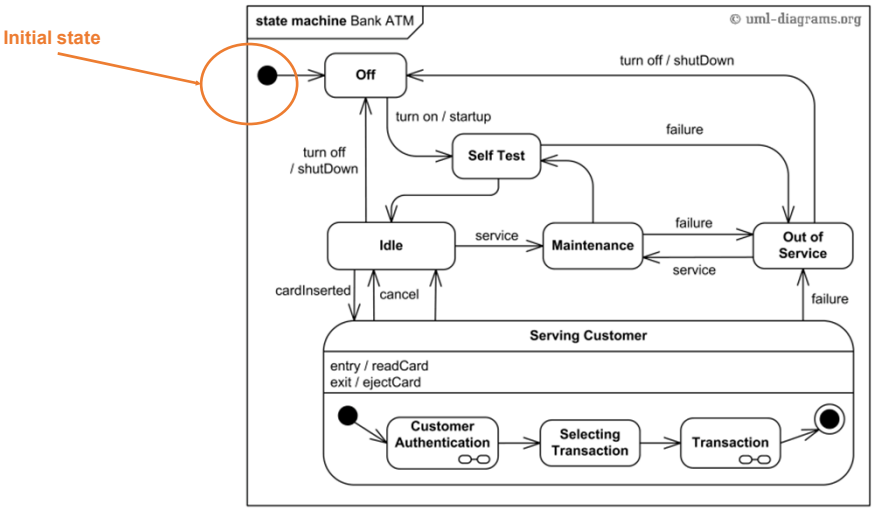
ATM Example



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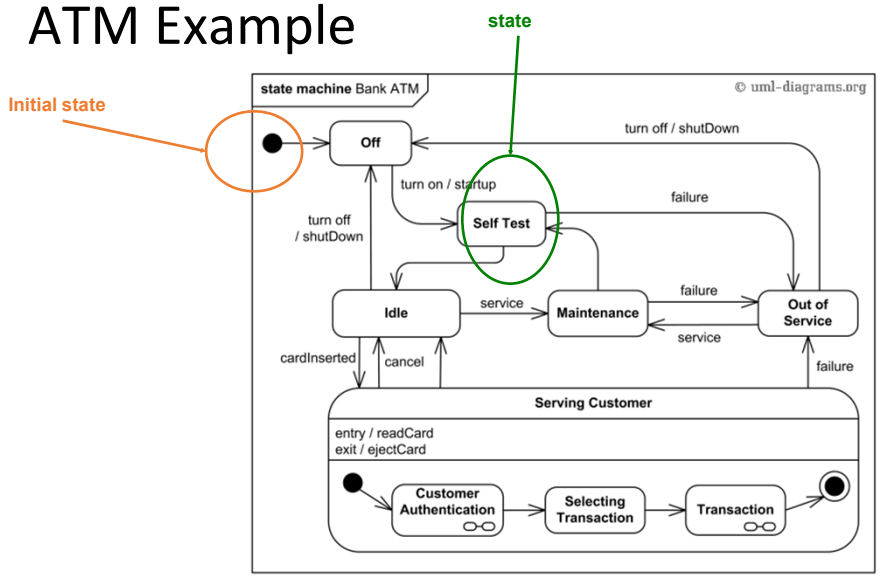
ATM Example



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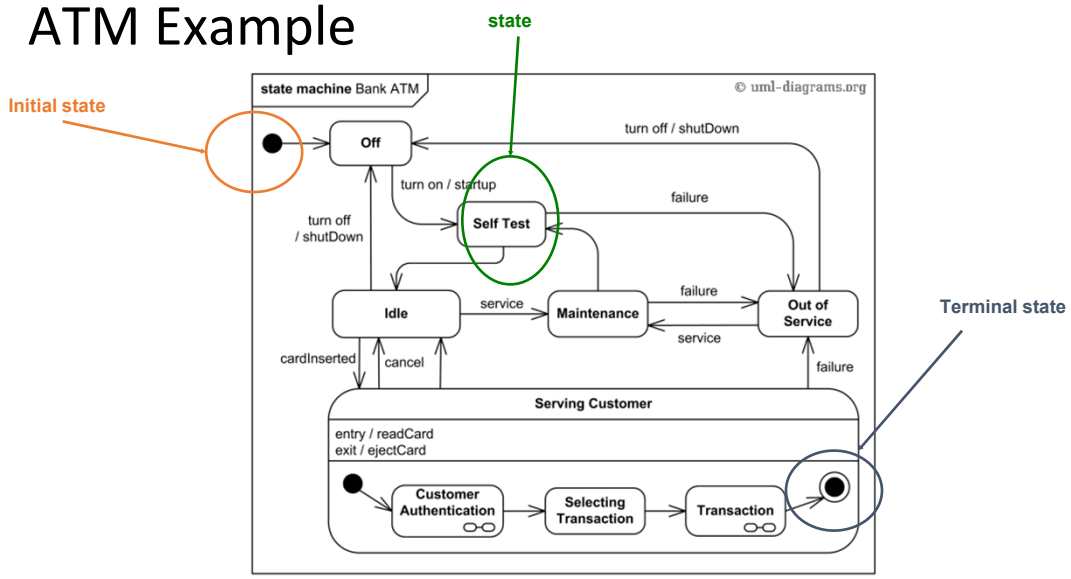
ATM Example



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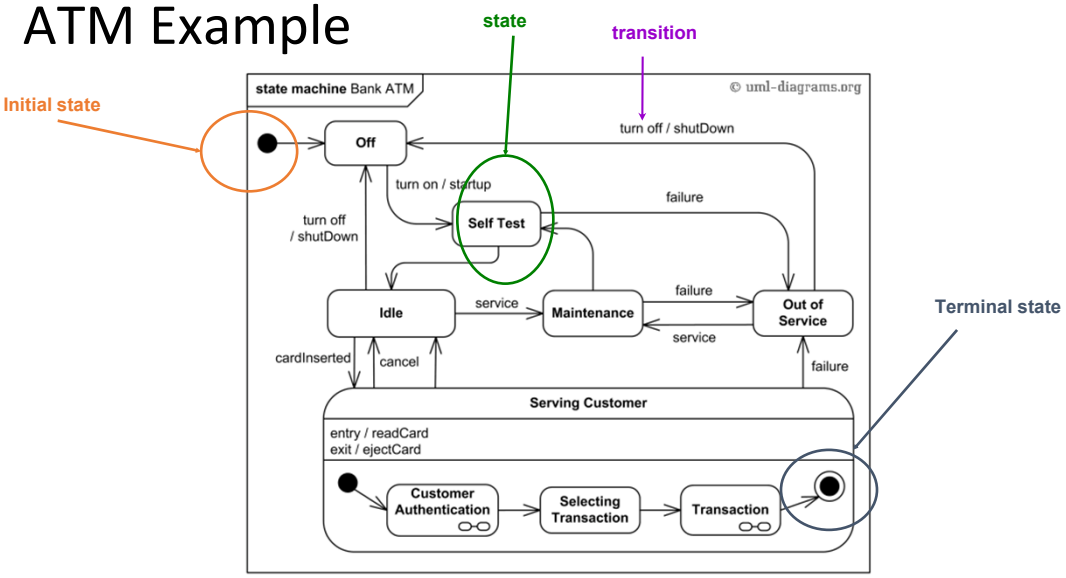
ATM Example



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Rules for State Diagrams

- There is one initial state (can be multiple final states).
- Every state can be reached from the initial state.
- From each state, there must be a path to a final state.
- Every transition between states must be labeled with an event that will cause that transition.
- When an event occurs, you can take only one transition. If you have multiple transitions with the same event, the guards must be mutually exclusive.
- Transitions that are not shown are illegal OR show transitions that cause errors.

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Uses

- Understand all paths through a system
- Testing all paths through a system (up to length n, when there are loops)
- Ensuring all error states recover elegantly

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Onboarding Project – Backend Design

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Requirements Update!

- CoffeeMaker is currently limited to only 4 ingredients. Our update will allow arbitrary ingredients!
  - UC2: Add Recipe – updated
  - UC4: Edit Recipe – updated
  - UC5: Update Inventory – updated
  - UC7: Add Ingredients – new
- Team Portion of OBP: UC5 & UC7
- Individual Portion of OBP: UC2 & UC4

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Backend Design Expectations

- Static Design – Class Diagram
  - Team – update backend design for UC5 (Add Inventory) and UC7 (Add Ingredients)
  - Individual – update backend design for UC2 (Add Recipe) and UC4 (Edit Recipe)
- Dynamic Design – Sequence Diagrams
  - Team – sequence diagram for ***one*** scenario related to UC5 and/or UC7, scenario description, and justification for successful implementation
  - Individual – sequence diagram for ***one*** scenario related to UC2 and/or UC4, scenario description, and justification for successful implementation

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