CSE870 Software Engineering
Object-oriented Modeling:
Class Diagrams

Acknowledgements: M. Langford, M. Heimdahl

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Structural Models

- ***Structural models focus on system organization***
  - What are the ***system components***, what are their ***characteristics***?
  - How are the ***relationships*** between components?
- ***UML Structural Models***
  - ***Package Diagrams*** – visualizes ***how various UML models are grouped*** together
  - ***Component Diagrams*** – visualizes ***groups of classes*** into system components
  - ***Class Diagrams*** – visualizes a system's ***object-oriented classes***
  - ***Deployment Diagrams*** – visualizes the ***physical hardware*** for a system

Class diagrams are the ***most common*** UML diagram you will encounter.

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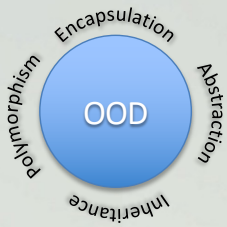
Object-Oriented Design



- ***Four principles of Object-Oriented Design***
  - ***Encapsulation***
    - Ability to ***group data*** into a single entity with public/protected/private access
    - Ex: Obstacle avoidance(bundle together relevant elements: detection, classification, etc.)
  - ***Abstraction***
    - Ability to ***hide data*** from external entities (public/protected/private access)
    - Ex: Obstacle detection (abstract details, such as technique used, identification, etc.)
  - ***Inheritance***
    - Ability to ***derive and add properties*** to existing entities (promotes reuse)
  - ***Polymorphism***
    - Ability to define ***alternative behavior*** to an entity based context

Not all programming languages are object-oriented.

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Programming Paradigms

- ***Procedural Languages (Imperative)***
  - Program is a ***series of statements*** or procedure calls
  - Focus: computations/functions
  - ***Examples***: Fortran, COBOL, BASIC, C
- ***Functional Languages (Declarative)***
  - Program is a ***composition of chained functions***
  - Focus: functions; (computation, parameters, procedures)
  - ***Examples***: Lisp, Scheme, Haskell, Erlang
- ***Logic-based Languages (Logical, inference)***
  - Program stmts express facts and rules about problems
  - Focus: logic
  - ***Examples***: Prolog, Parlog, Datalog
- ***Object-Oriented Languages***
  - Program is a ***collection of interacting objects (application)***
  - Focus: data
  - ***Examples:*** Java, C#, C++, Python

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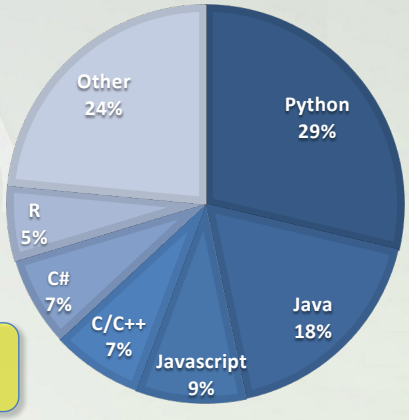
Popularity of Programming Languages

- ***PYPL: PopularitY of Programming Languages*** [PYPL 2024]
  - Based on ***frequency of Google*** searches for tutorials
  - https://pypl.github.io/
- ***2024 Results***
  1. ***Python*** – Object-oriented
  2. ***Java*** – Object-oriented
  3. ***Javascript*** – Can be object-oriented
  4. ***C/C++*** – Can be object-oriented (C++)
  5. ***C#*** – Object-oriented
  6. ***R*** – Object-oriented properties

Object-oriented programming dominates.



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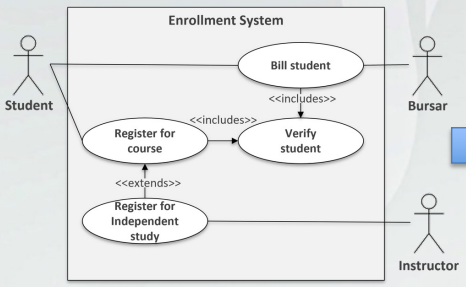
Class Diagrams for Domain Models

- ***Class Diagrams can be used early in the software process***
  - ***No code has been implemented***
  - ***Domain models*** describe ***objects in the real world***
  - Parse out ***each noun from use cases***



Potential Class
Student
Bursar
Instructor
Course
Independent Study

These nouns describe our problem space.

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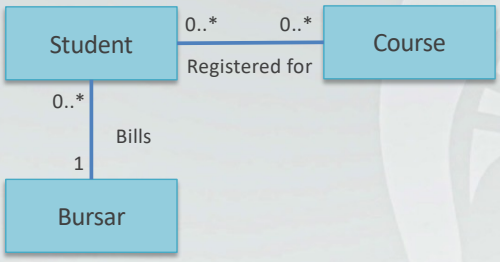
Elements of a Class Diagram



- ***Classes***
  - Drawn as a ***box***
  - Given a ***unique name***
- ***Associations***
  - Represents a ***relationship*** between classes
  - Drawn as a ***line***
  - ***Labeled*** to describe type
  - Annotated to indicate ***cardinality***

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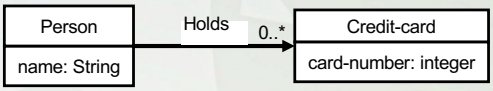
Multiplicity

One person holds one credit card

- One object can be related to many objects through the same association

One person can hold zero or more credit cards



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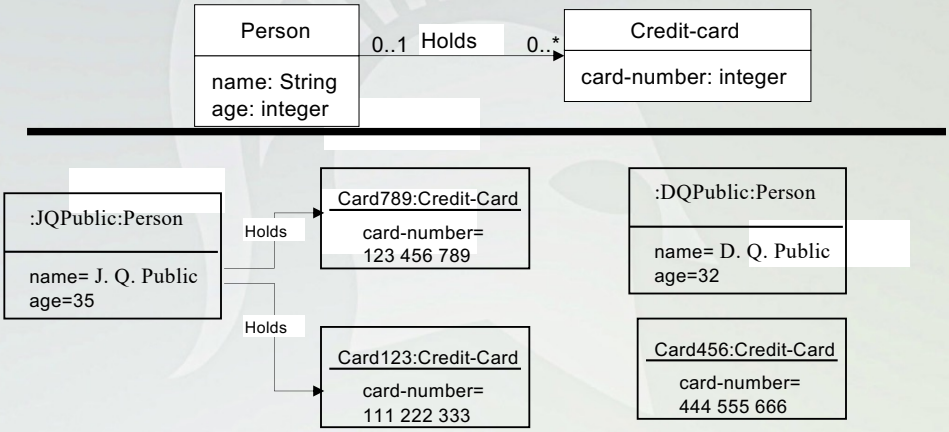
Multiplicity (Cont.)

•One person can hold zero or more credit cards (0..*)
•Each card has zero or one holder (0..1)



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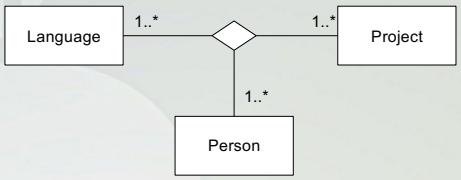
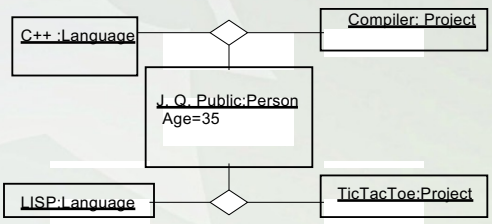
Higher order associations

- Ternary association
  - Project, language, person
- Seldom needed (and should be avoided)



Note: hexagons should be rectangles to represent instances



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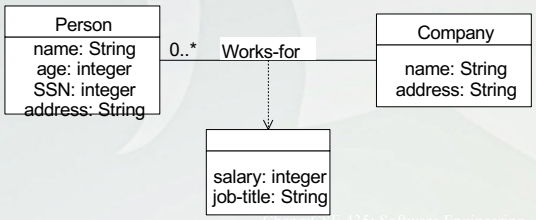
Link Attributes

- Associations can have properties the same way objects have properties

How to represent salary and job title?



Use a link attribute!

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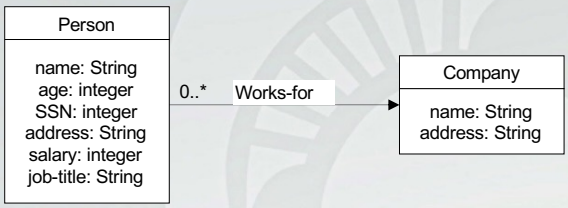
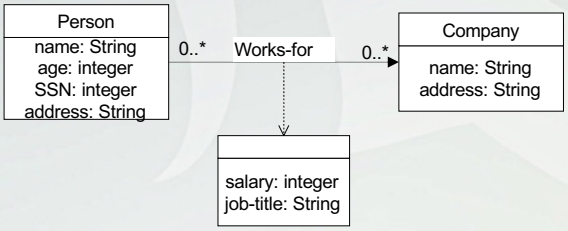
Folding Link Attributes



Why not this?

Salary and job title are properties of the job **not** the person



In this case, a link attribute is the only solution

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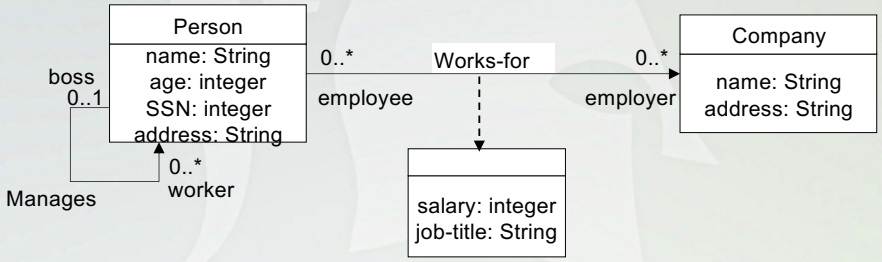
Role Names

- Attach names to the ends of an association to clarify its meaning



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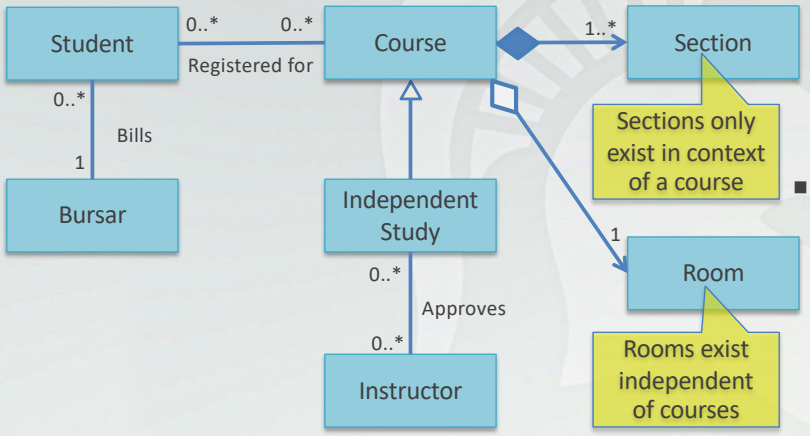
Special Types of Relationships



- ***Composition***
  - Indicates that ***one class contains another***
  - Drawn as an arrow with a ***filled diamond***
- ***Aggregation***
  - Same as composition, except ***contained class can exist independent of container***
  - Drawn as an arrow with a ***open diamond***

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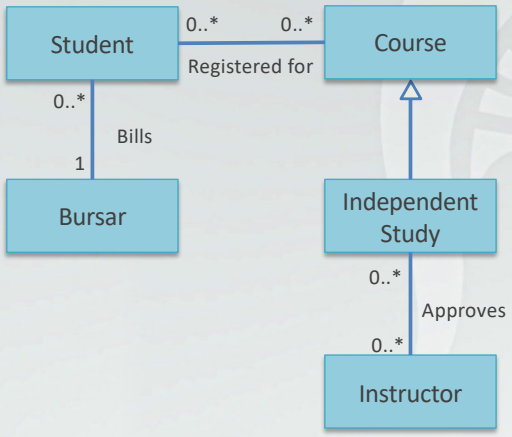
Special Types of Relationships



- ***Generalization/Inheritance***
  - Indicates that one class ***shares characteristics*** of a more general class
  - Drawn as an ***open arrow*** pointing to the more general class

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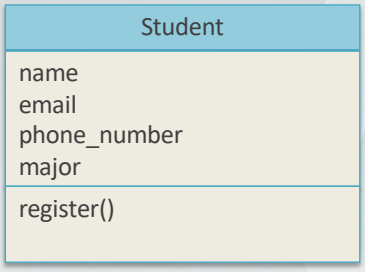
Defining Attributes and Operations



- ***Attributes***
  - ***Characteristics*** that distinguish individual instances of a class
  - Listed ***under class name***
- ***Operations/Methods***
  - ***Behavior*** of class
  - Listed ***under attributes***

Prior to design stage, class diagrams are usually not any more detailed than this.

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Domain vs. Design Model

- ***Domain* Models are used for *Requirements Modeling***
  - Describe the ***problem domain***
  - Objects in ***problem and solution space***
- ***Design* Models are used to model a *Software Implementation***
  - Describe ***object classes in a software system***
  - Include more ***implementation details*** (data types and hidden variable)
  - Classes may or may not correlate with classes in the domain model

Domain Model (Requirements)

Design Model (Implementation)

Class Diagrams can be used for ***a variety of modeling purposes***.

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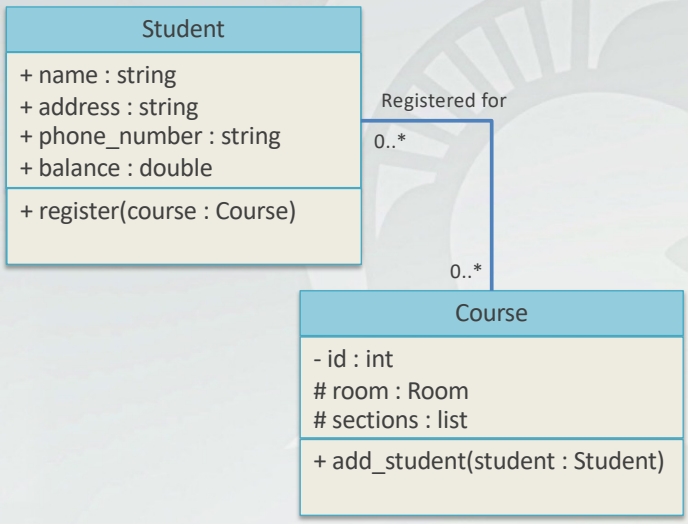
Implementation Details in Class Diagrams



- ***Data types***
  - Specifies ***type*** of each attribute
  - ***Follows attribute***, with a ***colon***
- ***Data access***
  - Indicates ***visibility*** of attribute
  - ***Precedes attribute***
  - (+) ***Public***
  - (#) ***Protected***
  - (-) ***Private***

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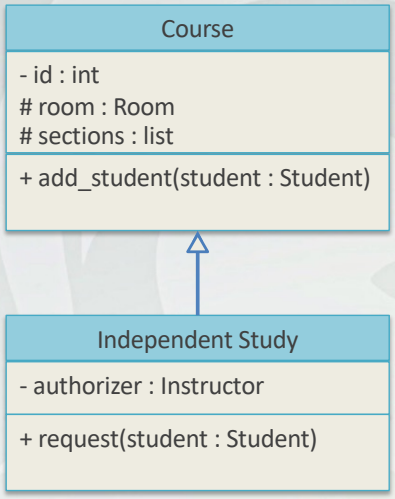
Inheritance of Attributes and Operations



- ***Parent Class:***
  - Define common attributes and operations
- ***Derived Classes***
  - Only include attributes and operations ***not in the parent*** class
  - Child class has access to all ***public and protected*** attributes

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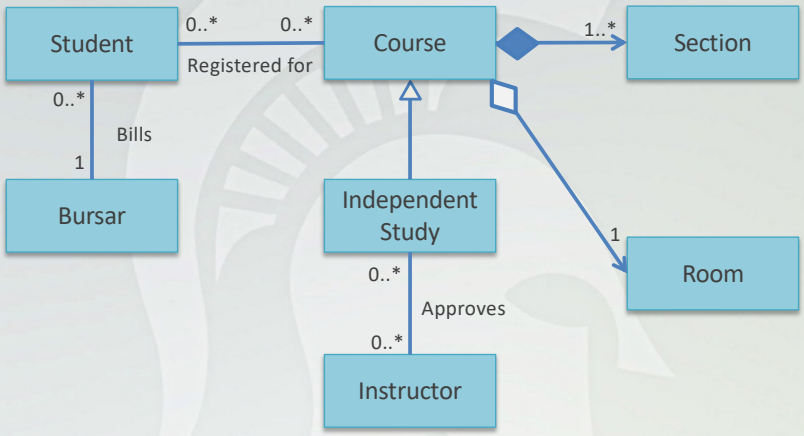
Domain Model Class Diagram (High-level)



Models real world ***objects and relationships for problem domain***.

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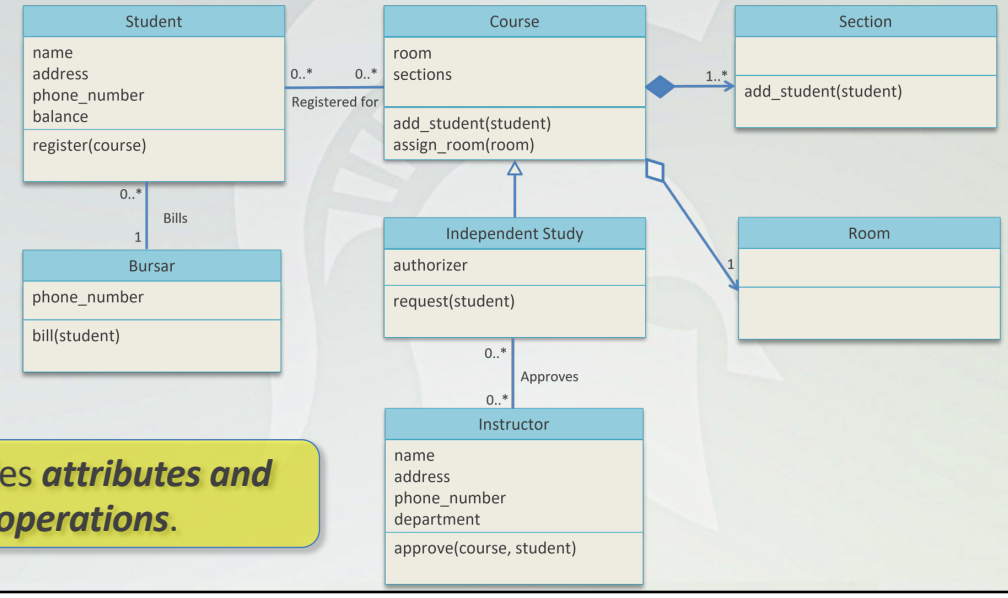
Domain Model Class Diagram (Detailed)



Includes ***attributes and operations***.

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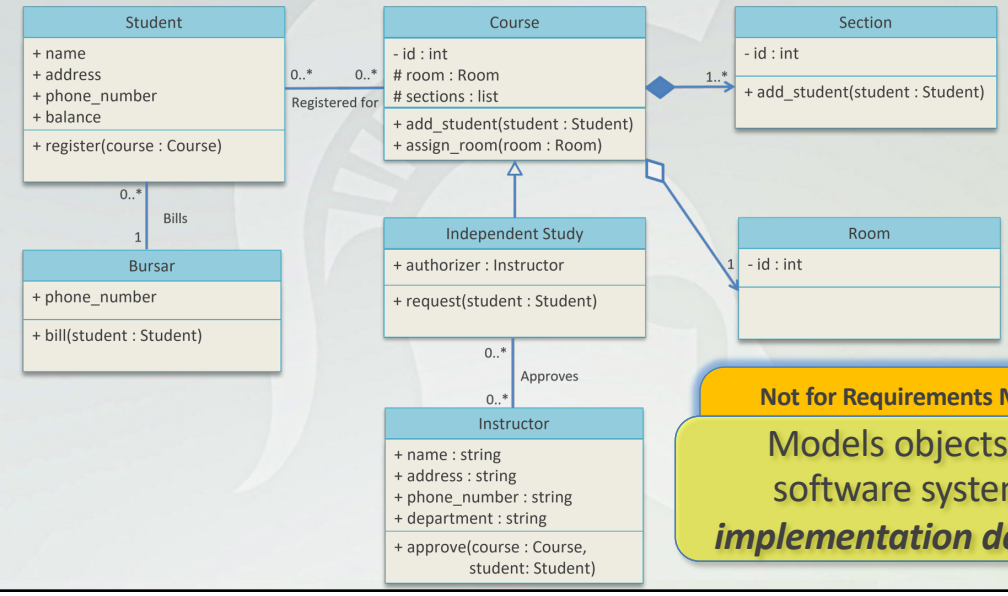
Design Model Class Diagram



Not for Requirements Modeling.

Models objects in software system, ***implementation details***.

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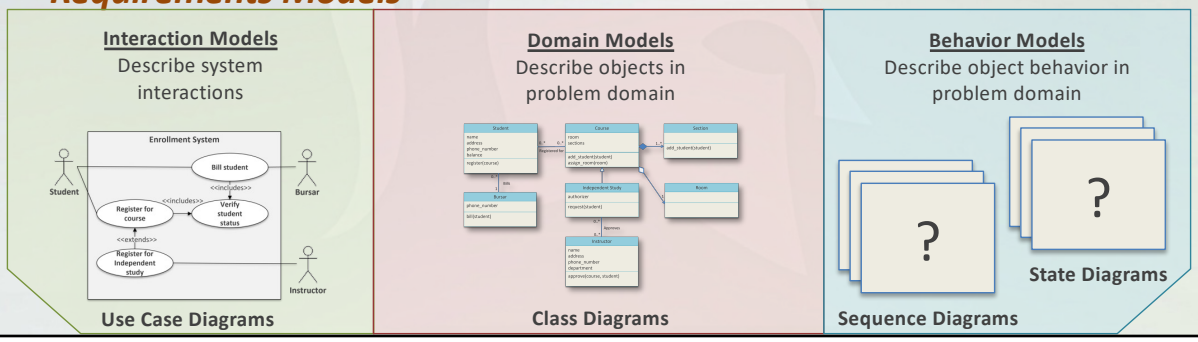
Summary

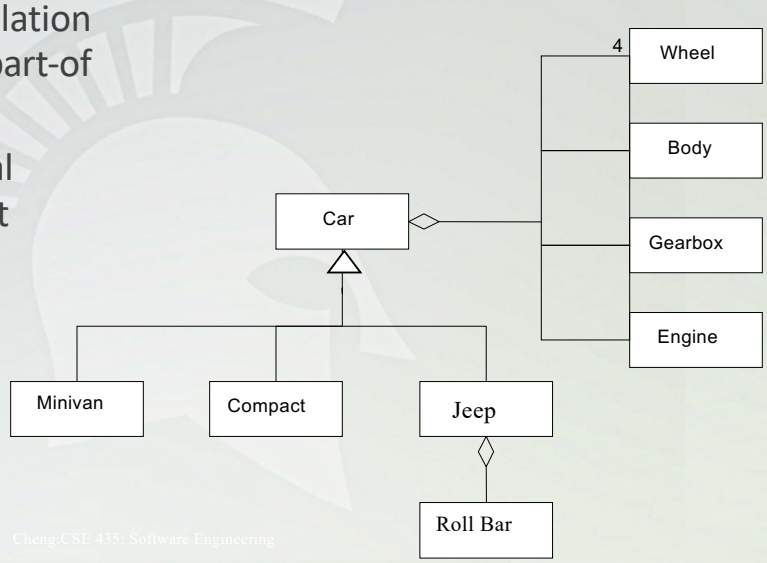
- ***Class Diagrams can be used for different types of models***
  - ***Domain Models*** – describe ***problem/solution space*** in early activities
  - ***Design Models*** – describe ***software implementation*** in later activities

- ***Requirements Models***



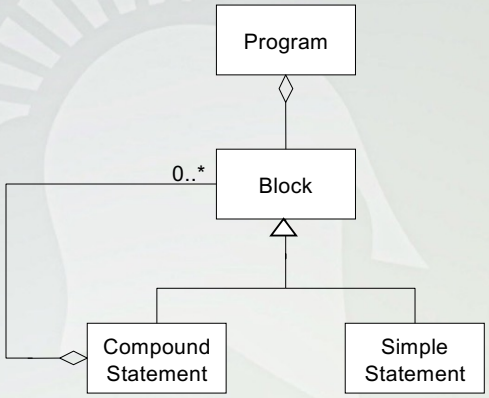
Aggregation Versus Inheritance

- Do not confuse the is-a relation (inheritance) with the is-part-of relation (aggregation)
- Use inheritance for special cases of a general concept
- Use aggregation for parts explosion



Recursive Aggregates

- A recursive aggregate contains (directly or indirectly) an instance of the same kind of aggregate



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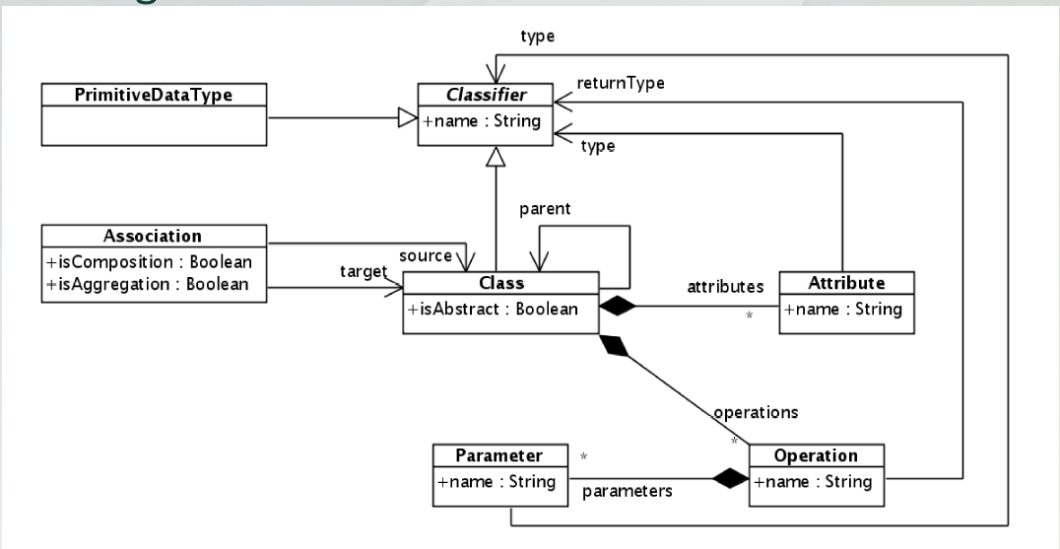
Class diagram Metamodel I



Eclipse.org

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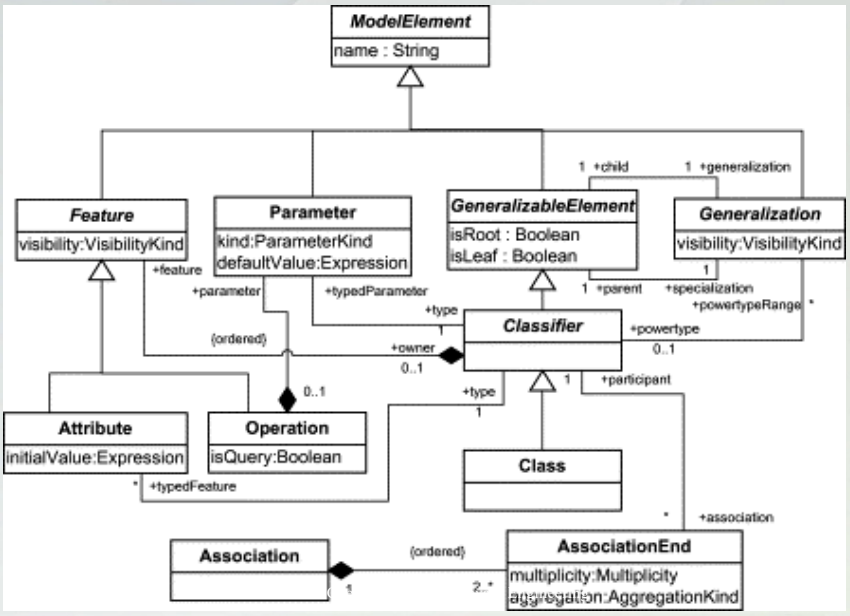
Class diagram Metamodel II



Science direct

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Use Case Metamodel I

uu: use case association relationship
_i: includes
_e: extends
_g: generalization
aa: actor relationship

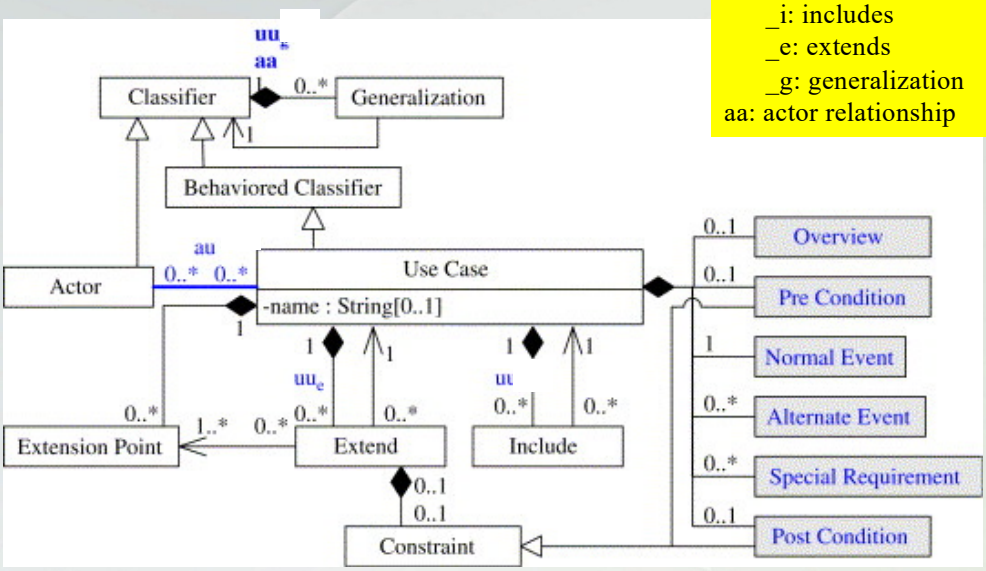

Image: Science Direct: ``Visual Modeling for Software Intensive Systems, Kooper et al, 2006.

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Use Case Metamodel II

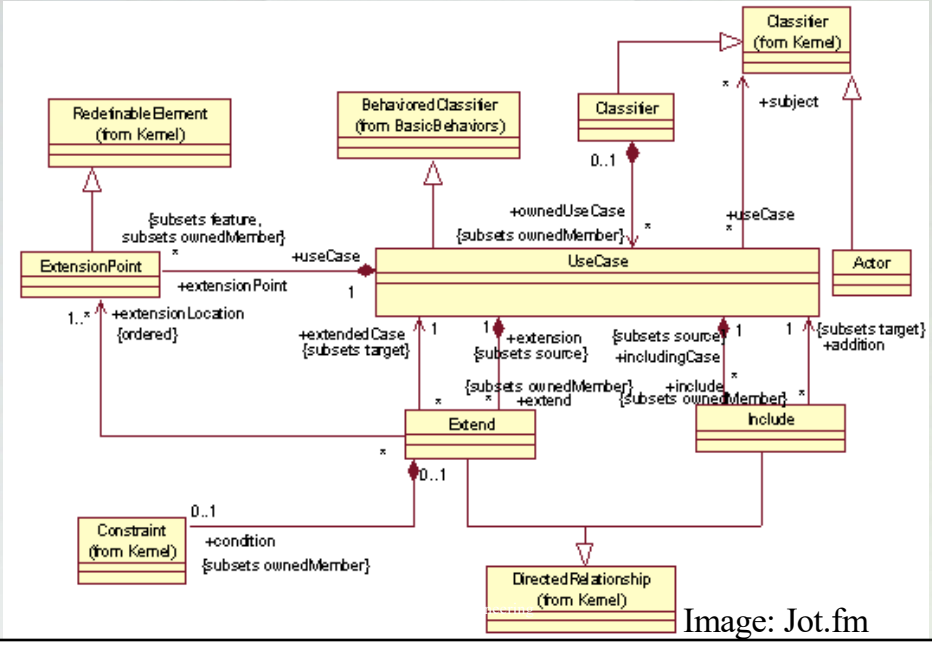
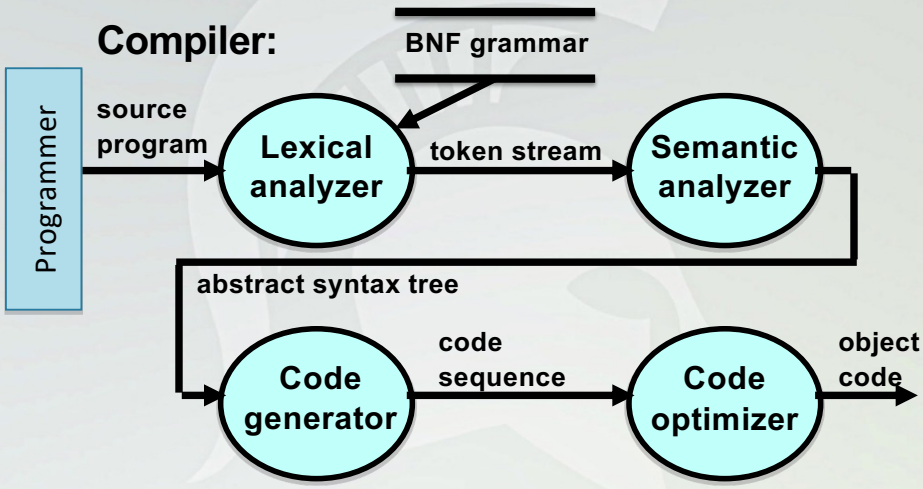


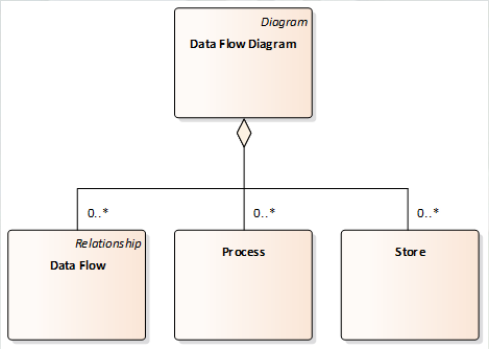
Image: Jot.fm

Data flow diagram (DFD)



Cheng:CSE 435: Software Engineering

Possible Metamodel for DFD



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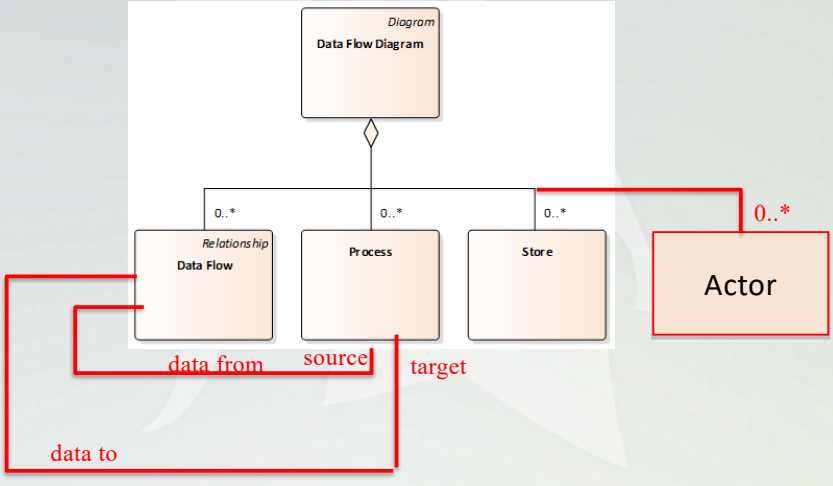
Revised Metamodel for DFD



PC:https://community.sparxsystems.com/white-papers/tag/metamodel

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Object Modeling Summary

- Classes
  - Name
  - Attributes
  - Operations
- Associations
  - Roles
  - Link attributes

- Aggregation/Composition
- Inheritance