Software Modeling: An Overview

CS6.401 Software Engineering

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Acknowledgements

The materials used in this presentation have been gathered/adapted/generate from various sources as well as based on my own experiences and knowledge

-- Karthik Vaidhyanathan

Sources:

1. Introduction to MDE, Ludovico Iovino, GSSI, Italy
2. UML@Classroom, An Introduction to Object-Oriented Modeling by Martina Seidl, Marion Scholz, Christian Huemer and Gerti Kappel
3. UML Modelling lecture, Dr. Raghu, IIIT Hyderabad

Source: Googe images

What is a Model?

Let us consider a real system

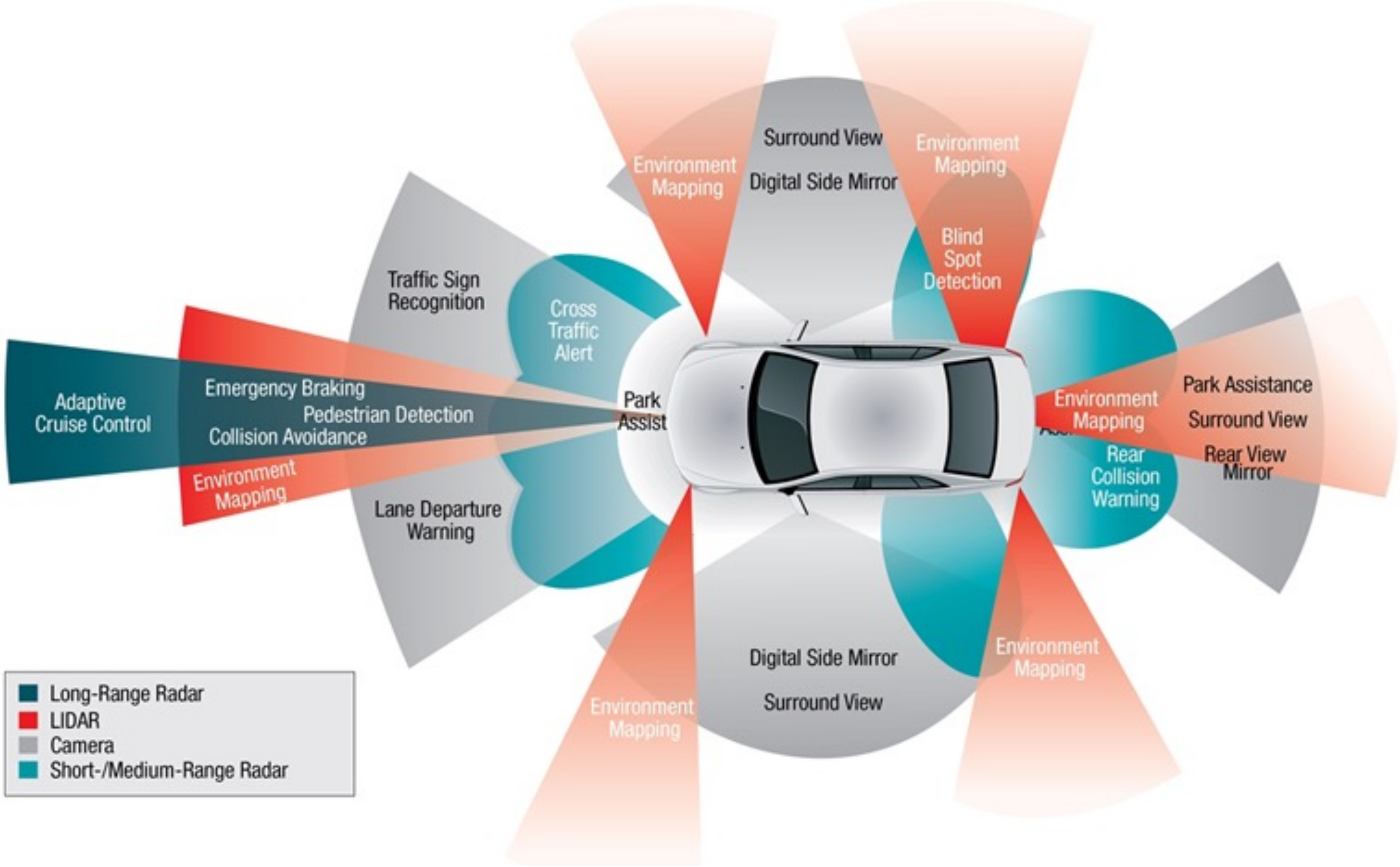
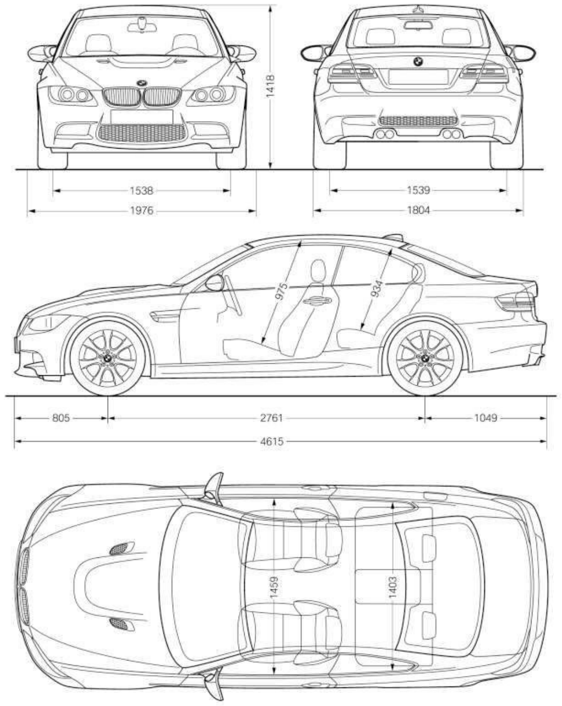


Image Source: machinedesign.com

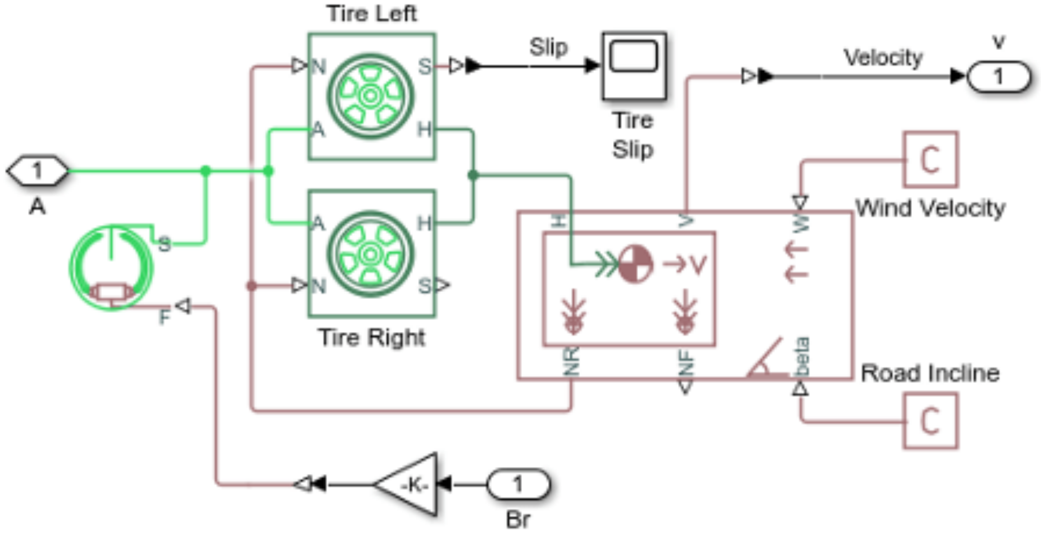
Let us now consider a model of the system

"The brain does much more than recollect. It compares, synthesizes, analyzes, generates abstractions."

-- Carl Sagan



Model from the designers

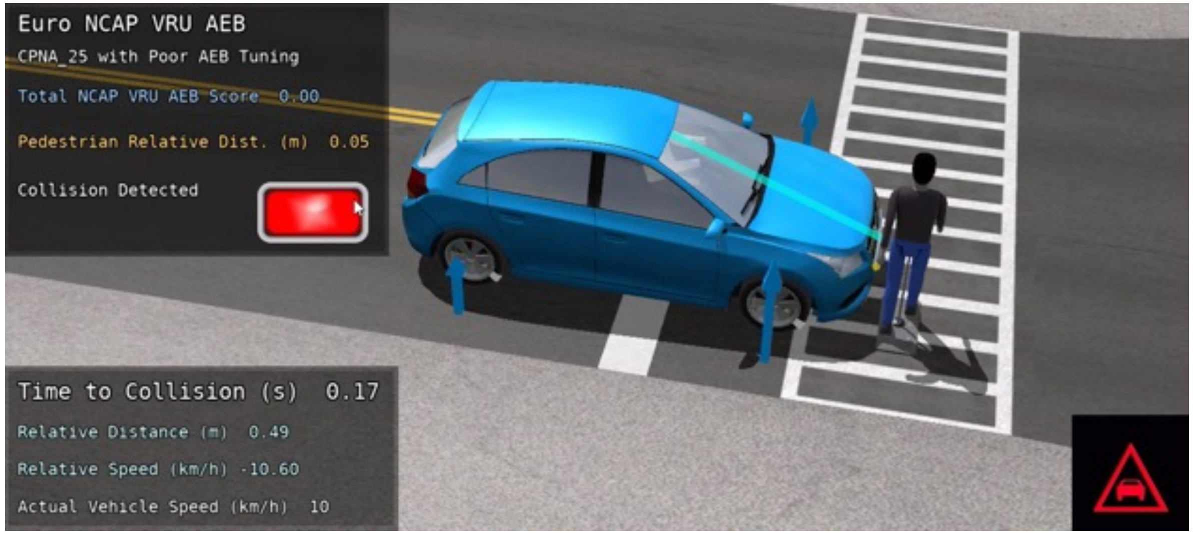


Model from the engineers

Model is a simplification of a reality. In other words, it is a blueprint of the system

Image source: Google images, mathworks

Modelling can serve more purpose



Euro NCAP VRU AEB

CPNA_25 with Poor AEB Tuning

Total NCAP VRU AEB Score 0.00

Pedestrian Relative Dist. (m) 0.05

Collision Detected

Time to Collision (s) 0.17

Relative Distance (m) 0.49

Relative Speed (km/h) -10.60

Actual Vehicle Speed (km/h) 10

Checking collision avoidance

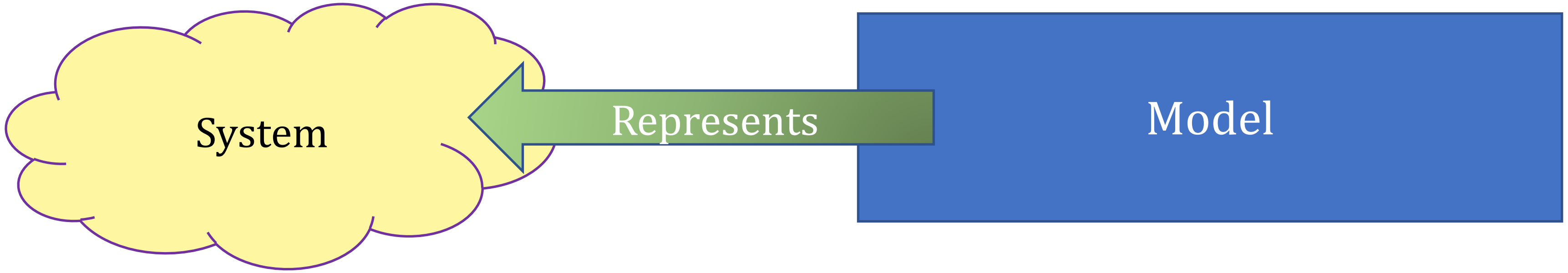
Checking if the traffic signs are followed

In essence models can be simulated with tools to perform analysis

Image source: carsim website

So what is a software model?

A simplified or partial representation of a real system, defined in order to accomplish a task or to reach an agreement.



Mapping: A model is always a mapping of some real system

Reduction: A model reflects only relevant set of properties of original system

Pragmatism: A model needs to be usable in place of the actual system with respect to some purpose

Quality of Model

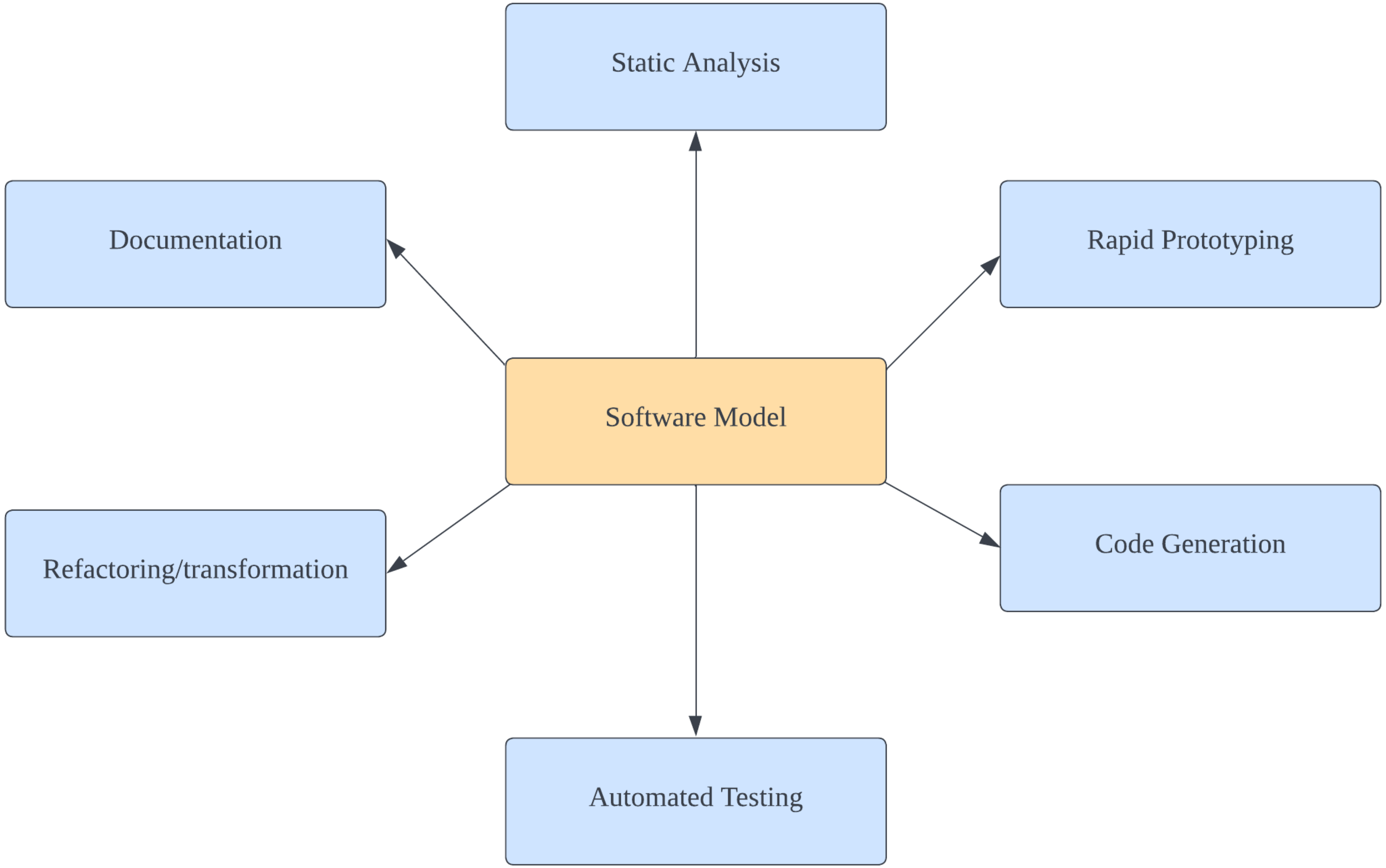
As per Bran Selic, five characteristics determine model’s quality

- Abstraction: A model should be reduced version of system [Omit unwanted]
- Understandability: Should be as intuitive as possible
- Accuracy: Reflect relevant properties as close to reality as possible
- Predictiveness: Enable prediction of interesting properties of system
- Cost-effectiveness: Cheaper to create models than the system

Glimpse into world of Model-driven Engineering

Model Driven Software Engineering

Shifting focus from code centric techniques to models



What is MDE? – Key Motivation

Models as a sketch

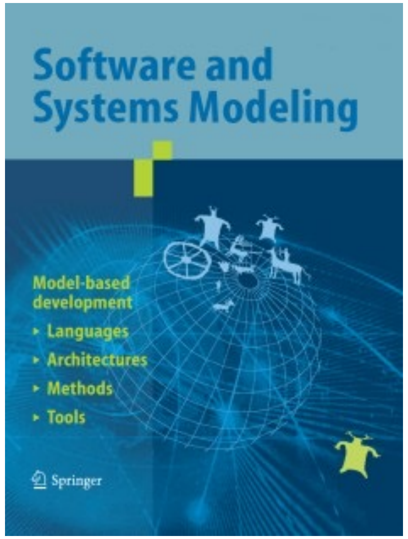
- Communication of ideas
- Objective: Modeling per se

Models as guidelines/blueprint

- Design decisions are documented
- Objective: instrumentation for implementation

Models as executable programs

- Generate code automatically
- Objective: models are source code and vice versa



Sosym journal

26th International Conference on
Model Driven Engineering Languages and Systems
MODELS 23
1-6 October 2023
Västerås, Sweden

Models conference

Image source: models and sosym website

What to Model?

Multiple ways to think about it

Algorithmic Perspective

- Main block of building the software is procedure or function
- Scale and new features affects maintainability and reasoning

Object oriented Perspective

- Main building block of all software system is object or class
- Contemporary view of software development

Object Oriented Modeling

- Model system as a collection of objects that interact with each other

- Tries to captures the real-world scenario
  - Everything is an object
  - Has a state and behavior: (Happy, angry)…(speaking softly, yelling…)
  - Can you model a person?

- Software objects are similar to real world objects:
  - Store state in fields (variables)
  - Behavior through methods (functions)

Objects vs Classes

	Real world	**Modelling World**
Object	Object represents anything that can be distinctly identified	An object has identity, state and behavior
Class	Represents set of objects with similar characteristics and behavior	It characterizes the structure of states and behaviors shared by its instances.

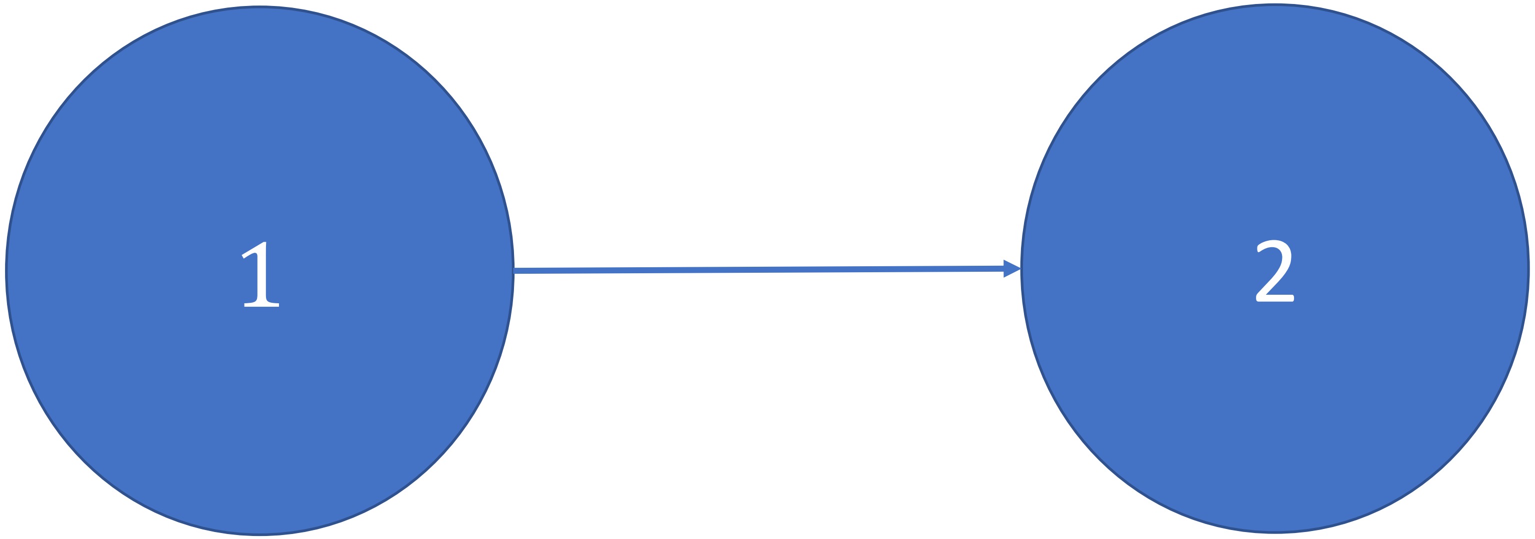
Object is like a variable of a class

Key Characteristics

- Abstraction: Hide irrelevant details (eg: Coffee machine)
- Encapsulation: Protection against unauthorized access (eg: Organization)
- Relationships
  - Inheritance: Derive classes from existing classes (eg: Real life inheritance!!)
  - Association: Relation between two classes (Aggregation, composition)
  - Dependency: Some form of dependency between two classes

How to Model?

How do you interpret this?



- 2 comes after 1
- 2 depends on 1
- 1 specializes/refines 2
- 2 listens to 1
- 1 contains 2

…

Can you create a model?

Think of a course management system like moodle. Can you create a model for the same?

Just use whatever knowledge you have, any type of diagram as per your knowledge is fine – Give a try!!

Modeling Languages

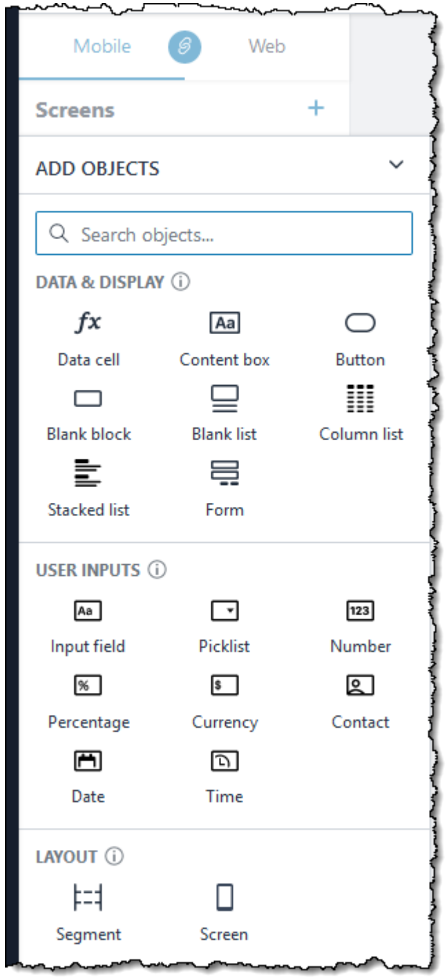
Largely classified into two types

- Domain-Specific Languages (DSLs)
  - Languages designed to model a certain domain
  - Examples: HTML, SQL, etc.

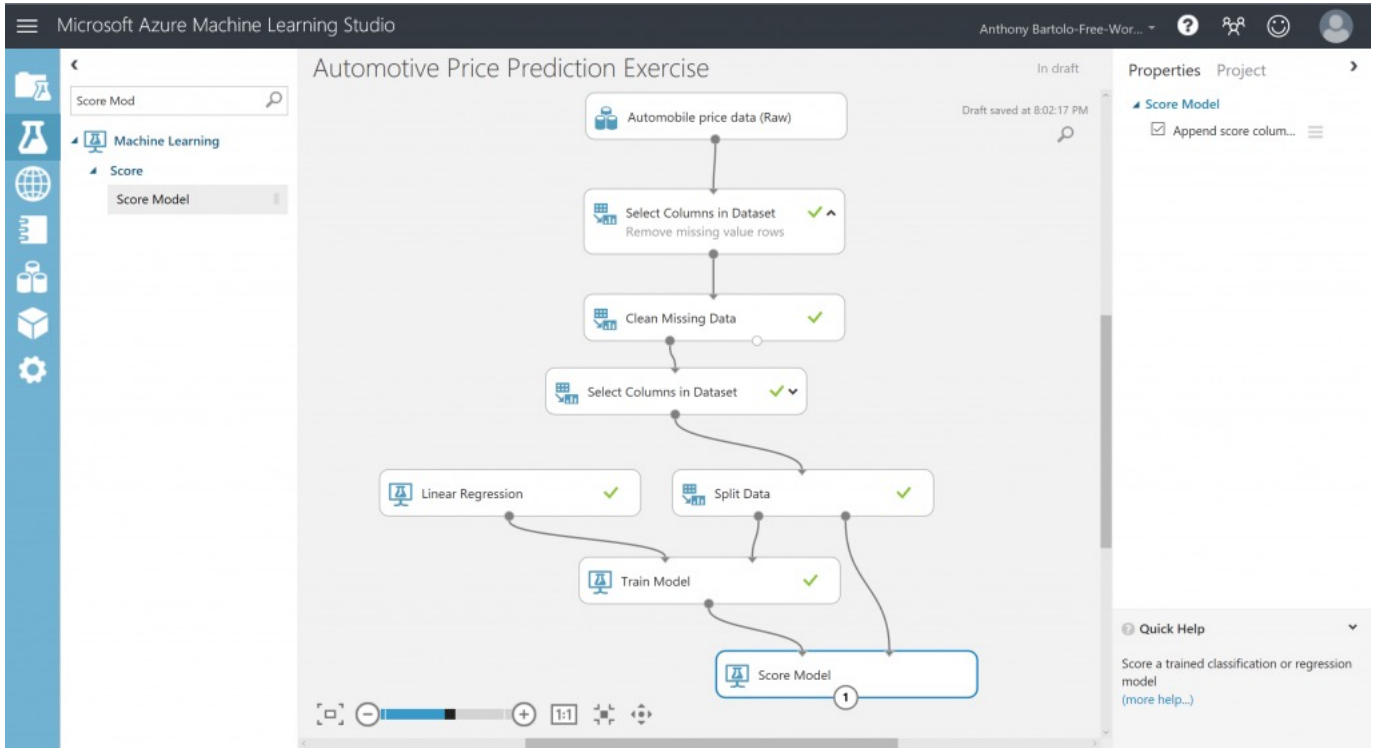
- General Purpose Modeling Languages (GPLs)
  - Languages can be applied to any domain for modeling
  - Examples: **UML**, XML, etc.

Wait is this similar to low code/no code?

Some Examples



AWS Honeycode


Microsoft Azure Machine Learning Studio
Anthony Bartolo-Free-Wor...
Score Mod
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Score Model
Automotive Price Prediction Exercise
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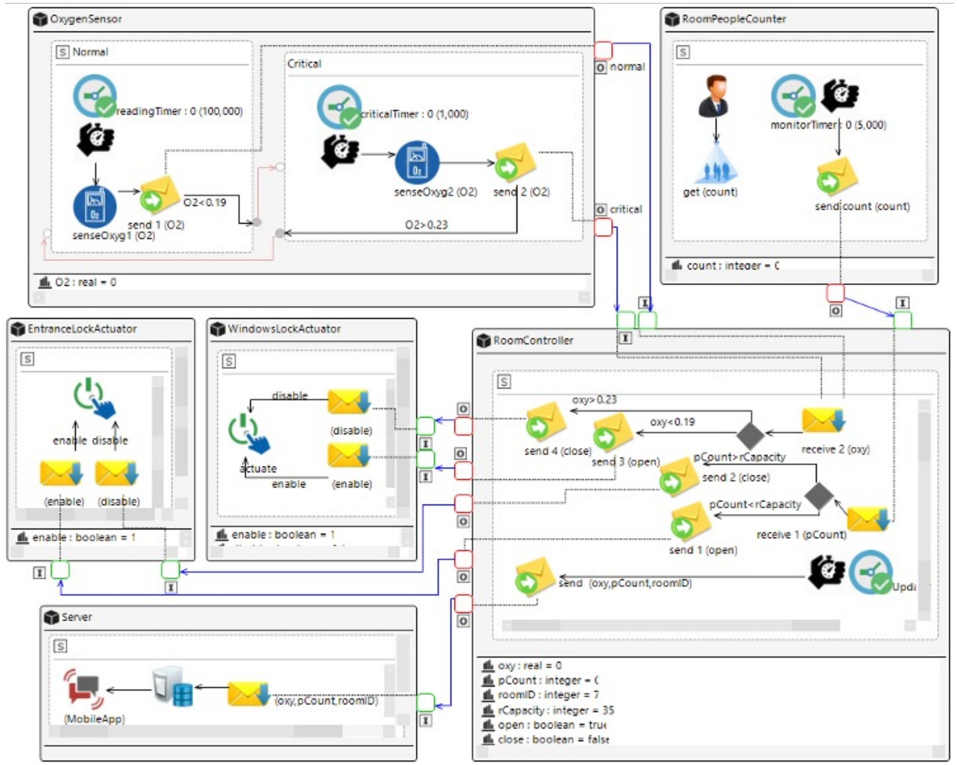
Draft saved at 8:02:17 PM
Automobile price data (Raw)
Select Columns in Dataset
Remove missing value rows
Clean Missing Data
Select Columns in Dataset
Linear Regression
Split Data
Train Model
Score Model
1:1
Properties
Project
Score Model
Append score colum...
Quick Help
Score a trained classification or regression model
(more help...)

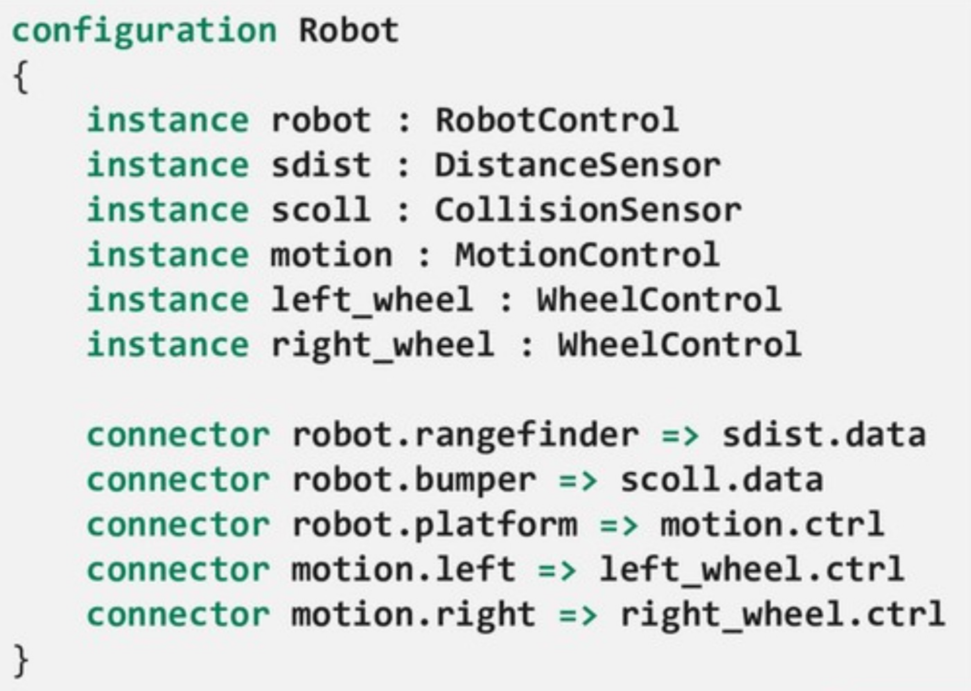
Azure Machine Learning Studio

Source: AWS, Azure (Microsoft Tech Community)

Some Examples - We can create our own too



CAPS modeling for IoT



```
configuration Robot
{
    instance robot : RobotControl
    instance sdist : DistanceSensor
    instance scoll : CollisionSensor
    instance motion : MotionControl
    instance left_wheel : WheelControl
    instance right_wheel : WheelControl

    connector robot.rangefinder => sdist.data
    connector robot.bumper => scoll.data
    connector robot.platform => motion.ctrl
    connector motion.left => left_wheel.ctrl
    connector motion.right => right_wheel.ctrl
}
```

ThingML modeling

Source: CAPS.disim.univaq.it, ThingML presentation@Models2018

In the Context of Our Course (GPL – UML)

Unified Modeling Language (UML): Brief History

- No common language to model until 1996
- GPL developed by industry consortium in 1997
  - Introduction of OOP in IT dates back to 1960’s
  - Required a standard representation: OMG
  - Three Amigos: Grady Booch, Ivar Jacobson and James Rumbaugh
- Based on multiple prior visual modeling languages
- Goal was to have a single language that could cover large number of SE tasks
- Current version of UML: 2.5.1 (as of Dec 2017)

Image source: Wikimedia commons

https://www.omg.org/spec/UML/

Unified Modeling Language (UML)

- Notation for OO Modeling
    - Use object orientation as basis
    - Model a system as collection of objects that interact with each other

- Graphical diagrams as a way to model systems
    - More clear (imprecise) than natural language (too detailed)
    - Capture an overall view of the system
    - Independent of language or technology

What UML is not?

- Not an OO Method or Process
- Not a visual programming language
- Not a tool specification

UML Diagrams

- 14 different diagrams
- Structure diagrams

for capturing static aspects of system

- Behavior diagrams

for capturing dynamic aspect of system

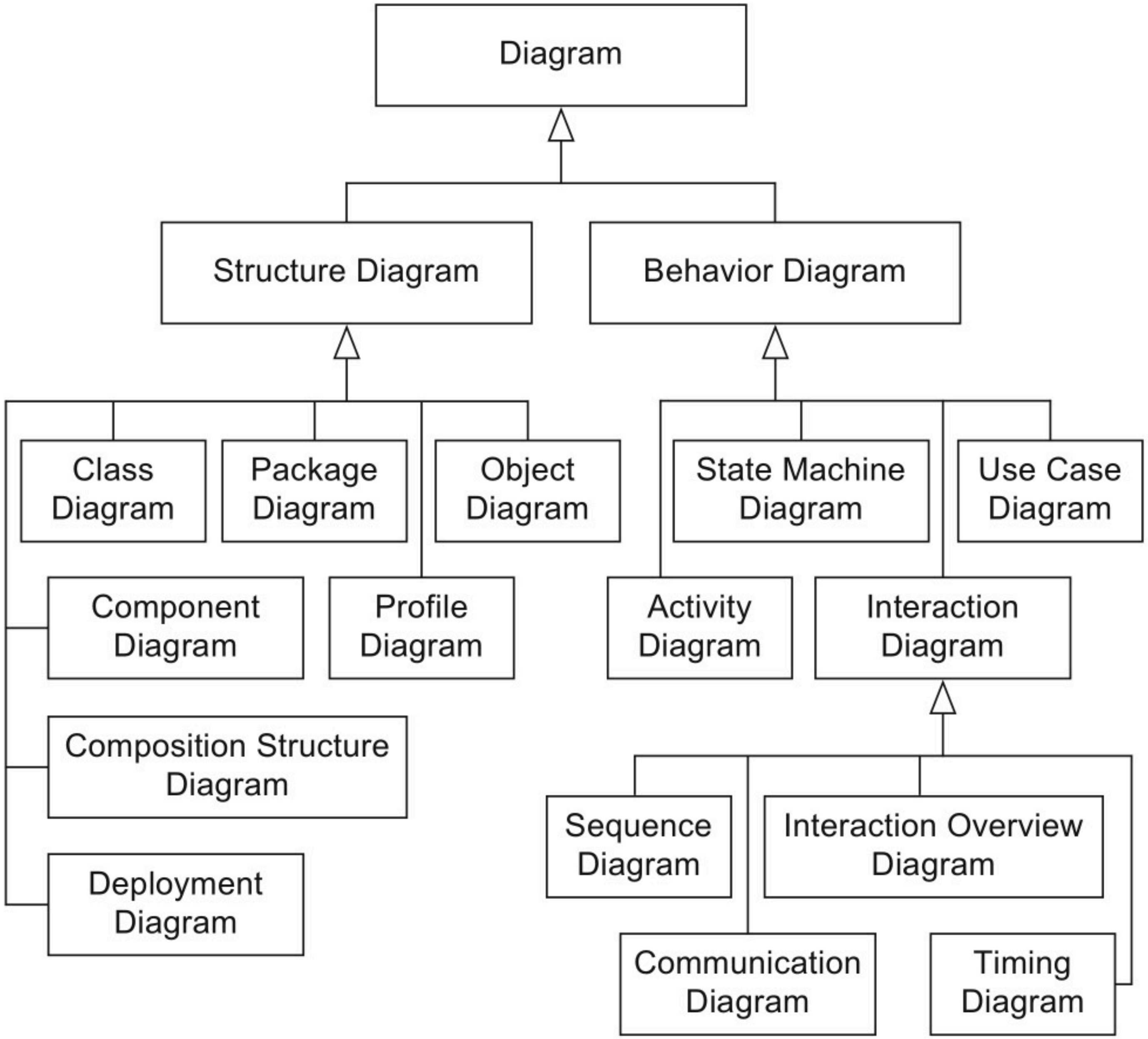


Image source: UML@classroom

Static Vs Dynamic Models

Static Model

- Describes the static structure of a system
- One of the most common diagrams: class diagrams

Dynamic Model

- Captures the dynamic behavior of a system
- Developed with help of state chart diagrams, sequence diagrams, etc.

In this unit: class diagram (static) and sequence diagram (dynamic)

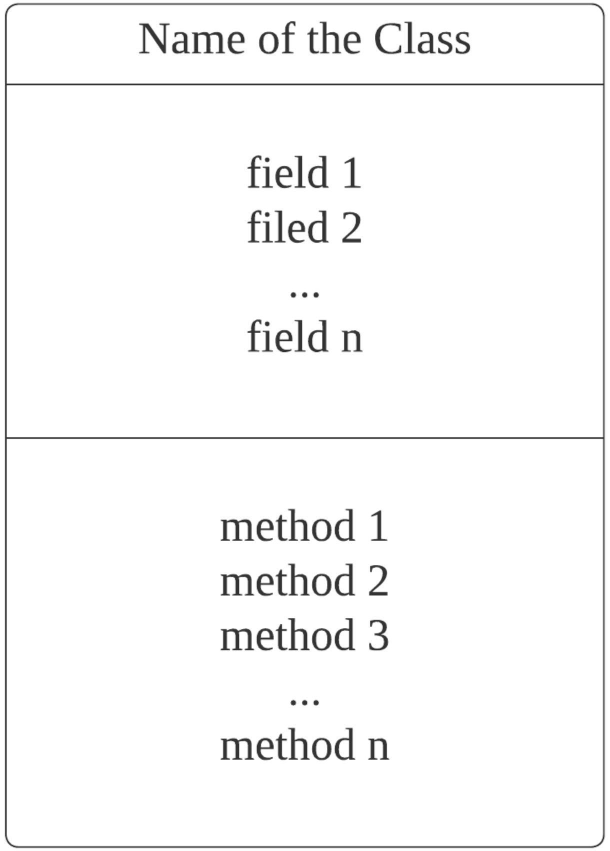
UML Class Diagram

UML Class Diagram

- Most common diagram in OO modeling
- Captures the static structure of a system
- Intuitively it is like a graph
  - Nodes represent the classes
  - Links represent the relationship among classes
    - Inheritance
    - Association (aggregation, composition)
    - Dependency

UML Class Diagram: Notation

Consists of three compartments



Name of the Class

field 1
filed 2
...
field n

method 1
method 2
method 3
...
method n

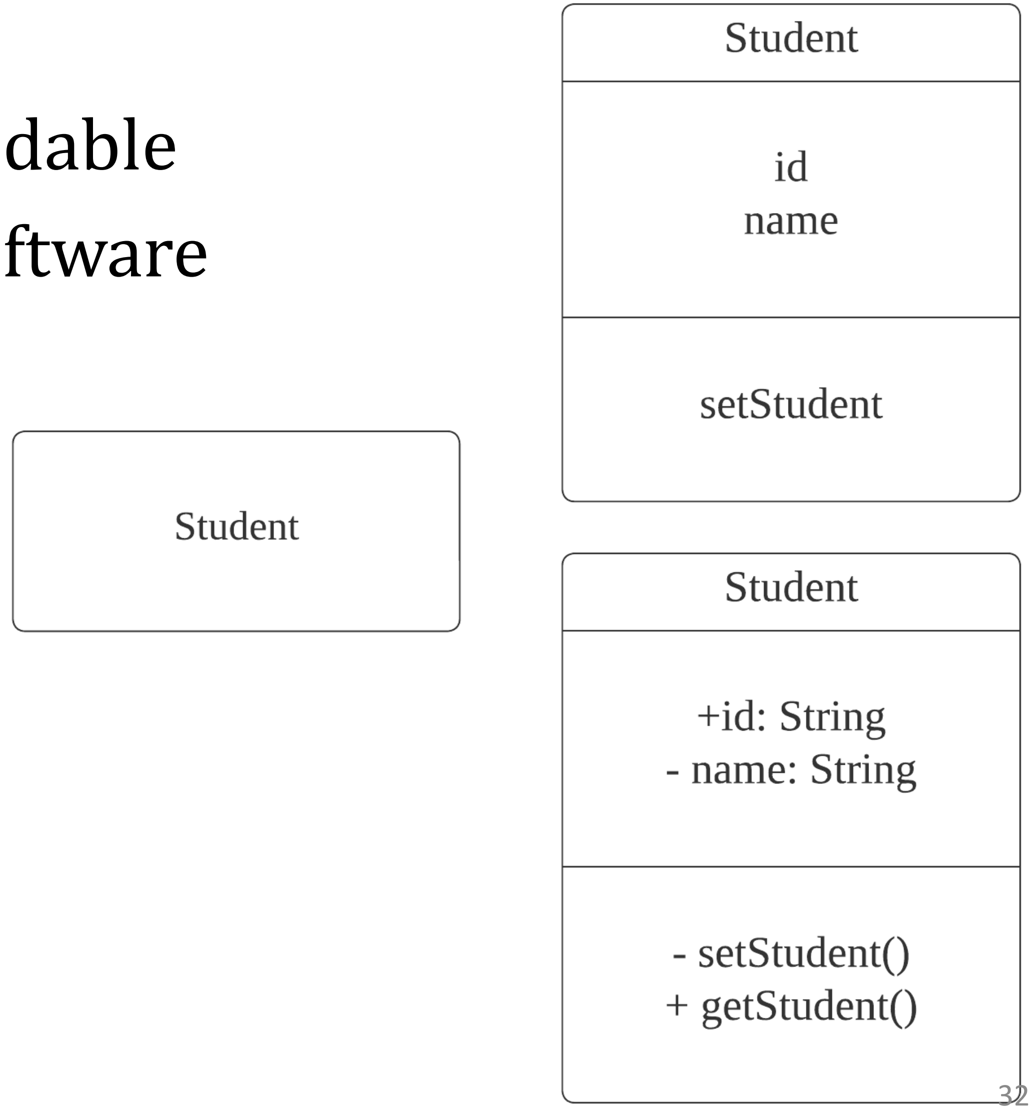
Class name - Pascal Casing, Singular noun, domain vocabulary

Fields/Attributes (state) - camel casing, name and type at basic level

Methods/operations (behavior) – camel casing, name, parameters, return value

UML Class Diagram: Always make use of abstraction

- Model has to be clear and understandable
- Detail with respect to the stage of software development process
- More low level analysis and development requires detailed information



Student

Student

id
name

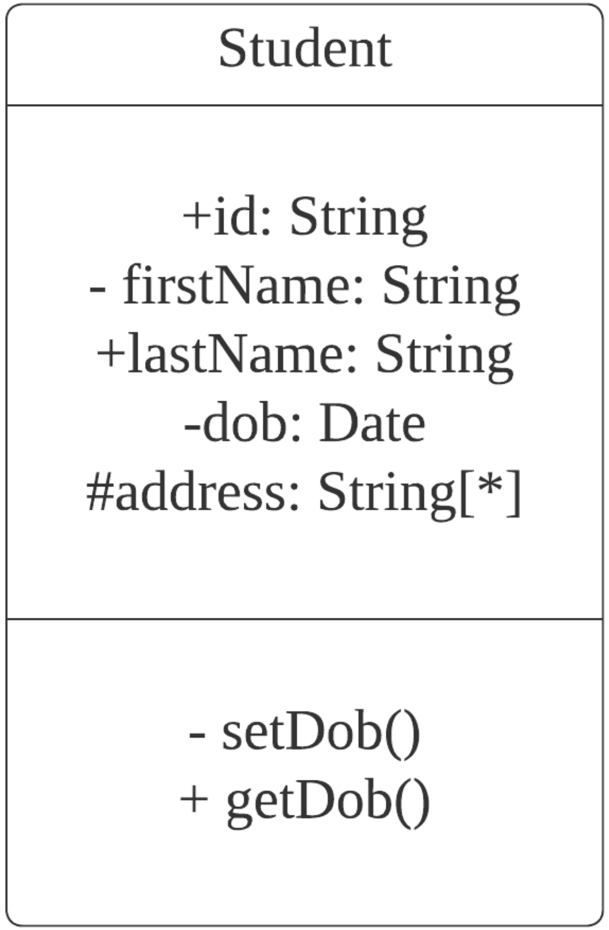
setStudent

Student

+id: String
- name: String

- setStudent()
+ getStudent()

UML Class Diagram: Specifying Attributes and Methods



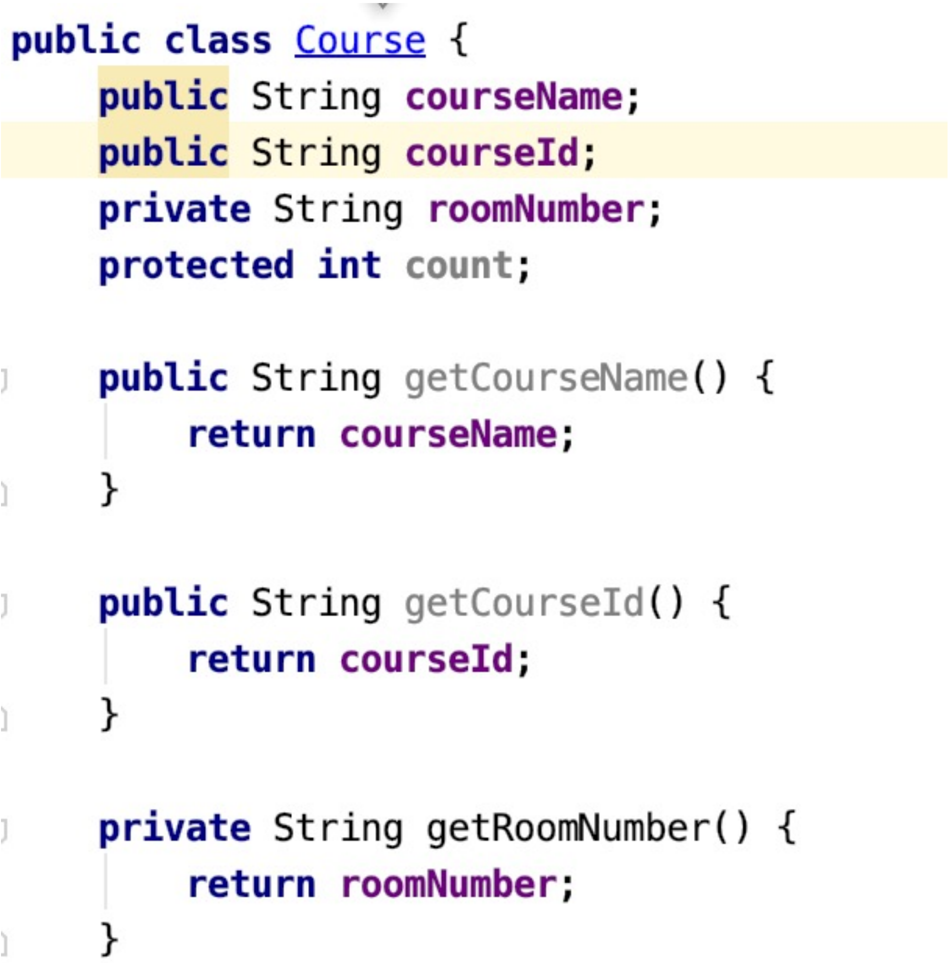
Student

+id: String
- firstName: String
+lastName: String
-dob: Date
#address: String[*]

- setDob()
+ getDob()

Name and Symbol	Description
public (+)	Access by objects of any class
Private (-)	Access only within the object
Protected (#)	Access by objects of same classes or sub-classes
Package (~)	Access by objects of the classes which are in same package

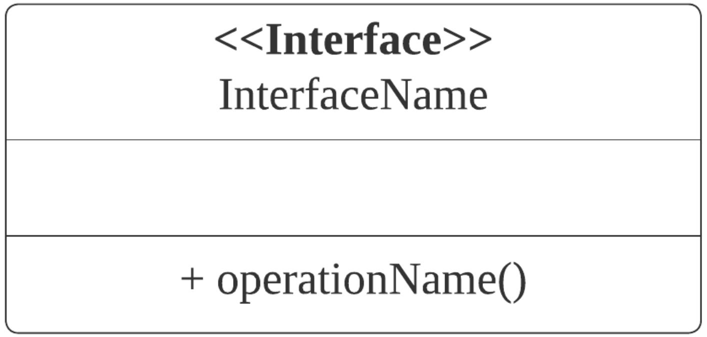
Create a class diagram for the following code



```java
public class Course {
    public String courseName;
    public String courseId;
    private String roomNumber;
    protected int count;

    public String getCourseName() {
        return courseName;
    }

    public String getCourseId() {
        return courseId;
    }

    private String getRoomNumber() {
        return roomNumber;
    }
```

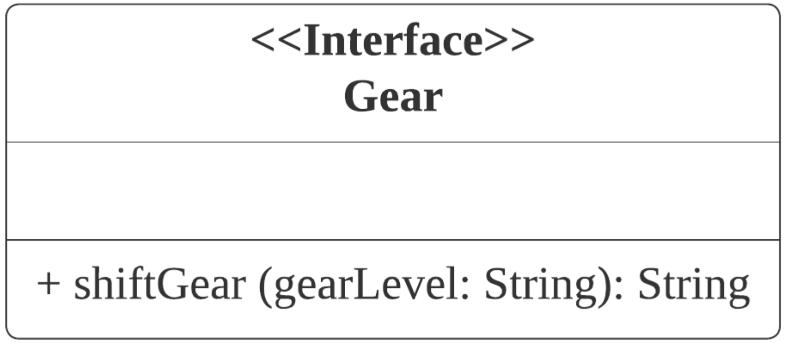
Interface and Notation for Interfaces

- In simple terms it’s a contract mechanism
- Mechanism to achieve abstraction, group classes, enforcer – No instance variables only constants
- Class can implement an interface – “implements” keyword (Java)



<<Interface>>
InterfaceName

+ operationName()



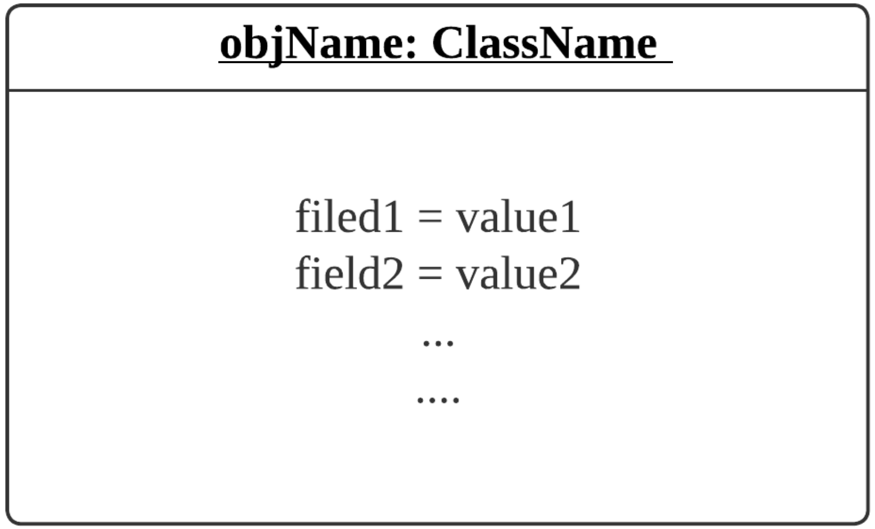
<<Interface>>
Gear

+ shiftGear (gearLevel: String): String

- Vehicles can implement Gear interface

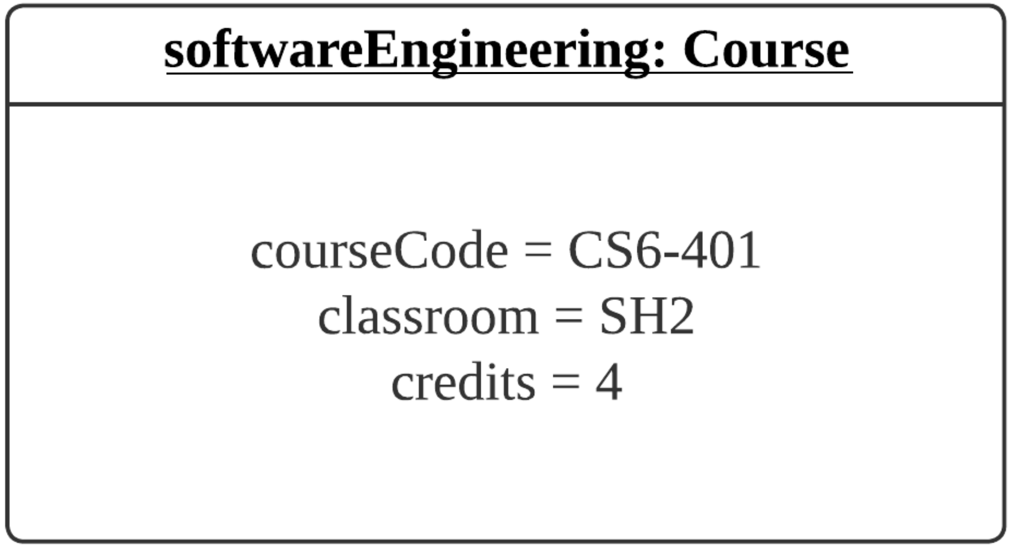
Notation for Objects

- Box with one or two compartments
- Remember to mention the class name



objName: ClassName

filed1 = value1
field2 = value2
…
….



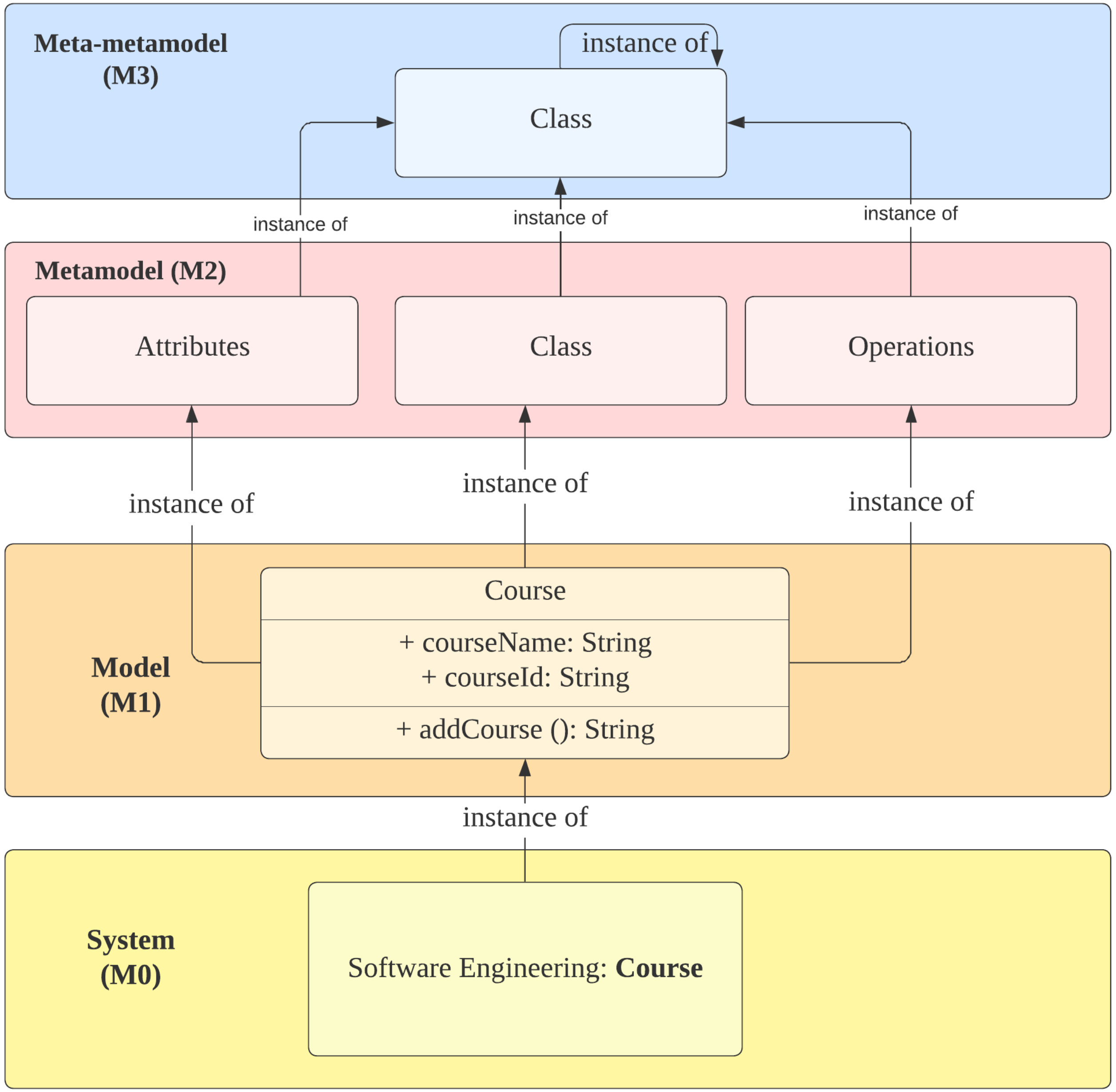
softwareEngineering: Course

courseCode = CS6-401
classroom = SH2
credits = 4

First part has object name and corresponding class name
Second part has list of fields and values

Models and Meta models

- Models of models
- Defines the rules for the different models
- For eg: a class needs to be defined in a particular way



Time to be Creative

Let’s assume that we want to build a course management portal (think of moodle), what could be some of the classes the corresponding attributes and methods? Can you think of some interfaces?

Modeling Relationships using UML

Three main relationships between classes

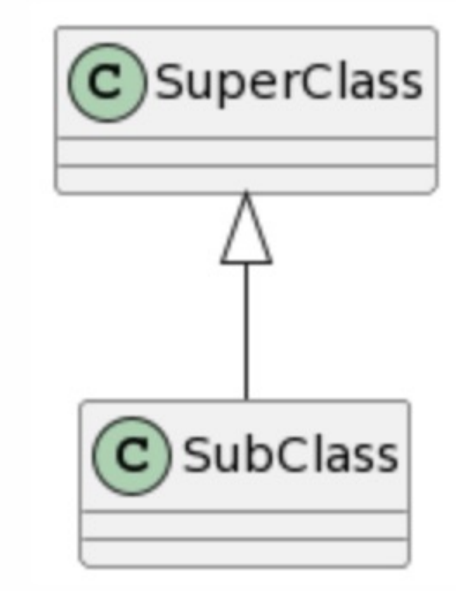
- Dependency
  - Class A uses Class B
- Associations
  - Class A affects Class B
  - Types: Aggregation and Composition
- Generalization
  - Class A is a kind of Class B

Inheritance in Java

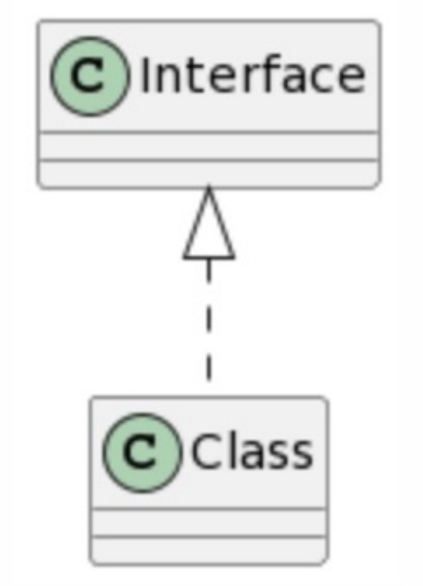
- Object acquires properties and behavior of parent object
- Create new classes based on existing classes
  - Derive classes from existing classes (”extends” keyword)
  - Parent class/super class – Class from which other classes are derived
  - Child class/sub class – Class that is derived from existing class
- **Object** class is the parent class for every class in java (java.lang.package)
- Eg: Vehicle class can be parent of car, bikes, etc.
  - Each car, bike can themselves be parent class for child classes – **How?**

Inheritance in UML

- UML provides easy ways to represent inheritance
  - Extension is called *specialization and generalization*
  - Implementation is called *realization*

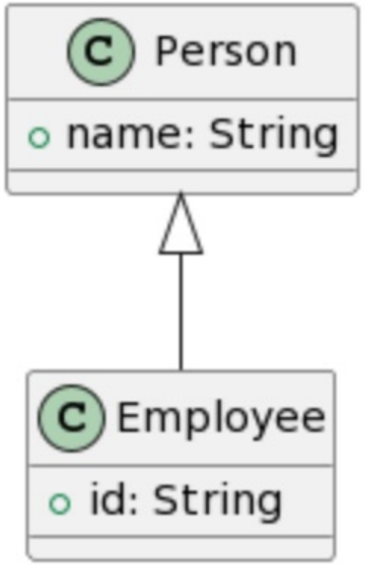


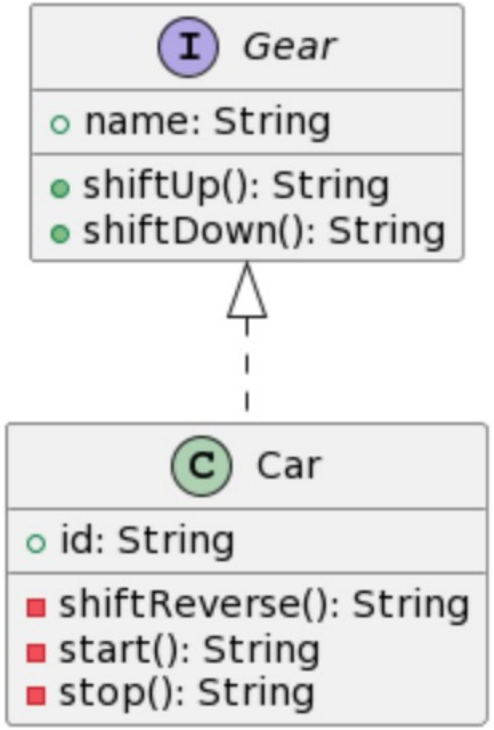
Extension of classes



Realization of interfaces

More Concrete Example





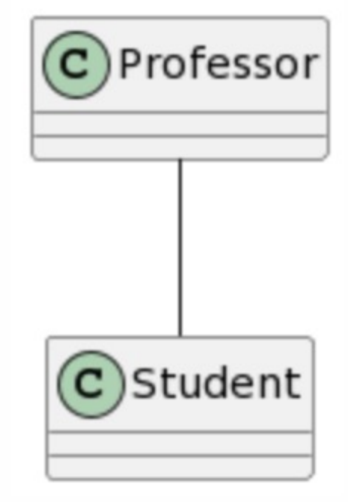
Time to be Creative

Draw a UML diagram showing possible inheritance relationship between different types of students in the class. What will be the abstract class (es)?

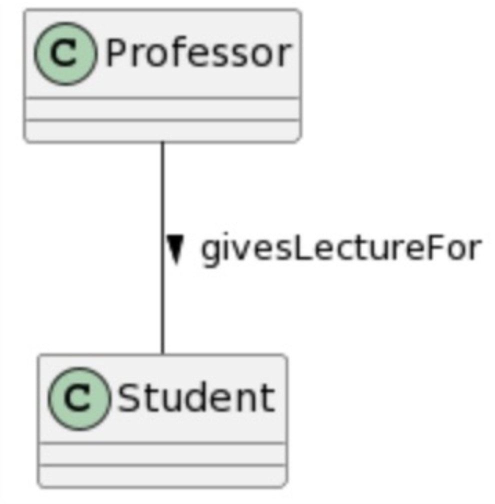
Hint: We have B.Tech, M.Tech, …..

Association

- Model links between instances of classes
- Identify the communication partners
- Use association names and reading directions (solid arrowhead) for labeling



What kind?

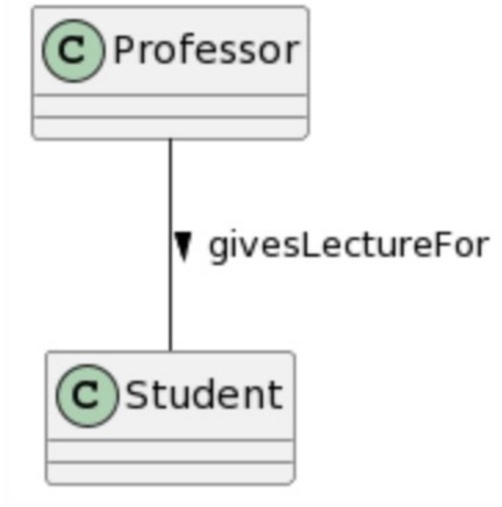


Professors gives lecture

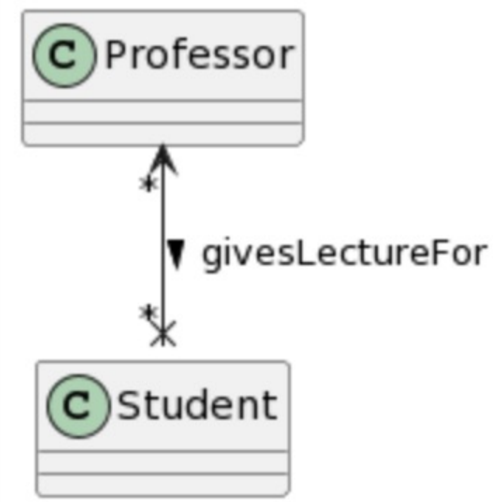
What about multiplicity?

Association – Navigability and Multiplicity

- Cardinality of the class in relation to the another - Multiplicity
- Navigation from one to another is possible – Navigability
- Navigability - Indicates who can access what (not reading direction)
- Usual assumption: Bidirectional navigability



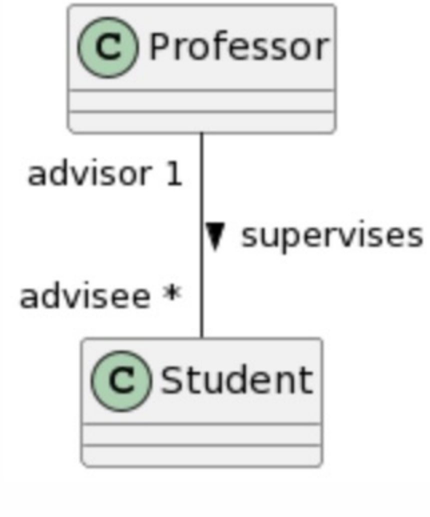
Bidirectional



Professor class cannot access public parameters/methods of student

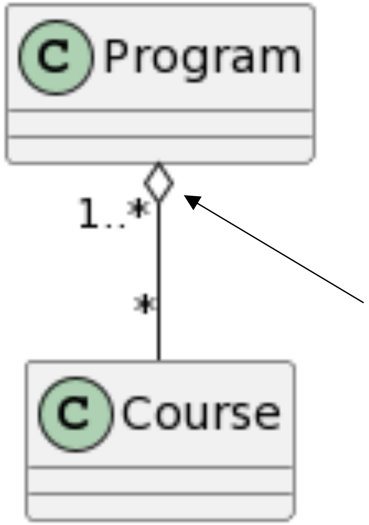
Association – Few more things

- May have optional role name
- Multiplicity specification is not always mandatory
  - min…max: closed (inclusive) range of integers
  - n: single integer
  - 0..*: entire set of non-negative integers

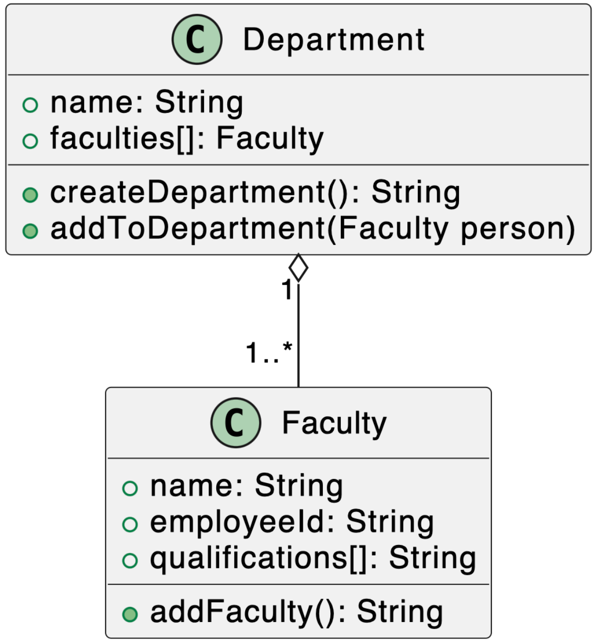


Aggregation

- Special form of association - Parts-whole relationship
- Used to express that a class is part of another (hollow diamond)
- Combination of independent objects (eg: Program and course)



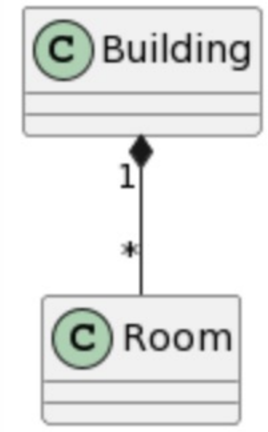
Represented by a hollow diamonc



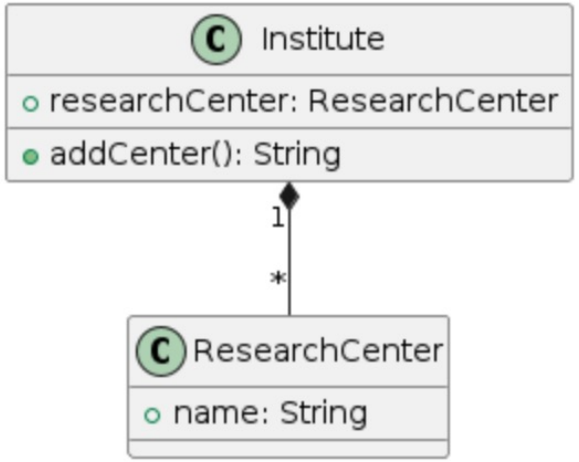
Another example

Composition

- Dependency between composite objects and its parts
- If the composite object is deleted, the parts are also deleted
- One part can be contained in at most one composite object at a time
  - Max multiplicity at the aggregating end is 1 (closed diamond representation)



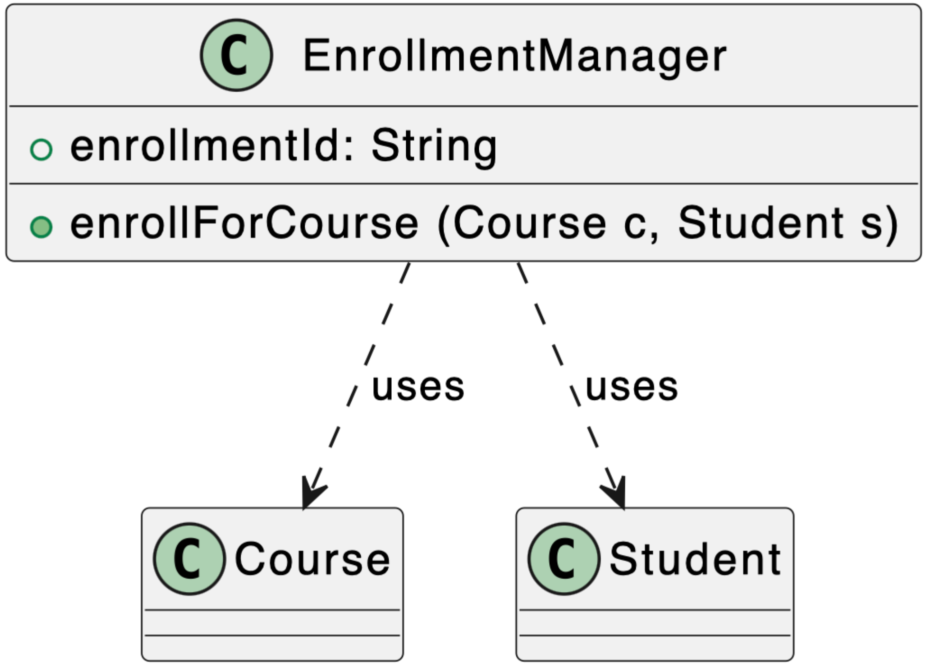
Building is composed of multiple rooms



Adding centers from Institute

Dependency

- One class uses another class <<uses> relationship
- There is no conceptual link between the objects of the classes
- One may refer the other or vice versa



C EnrollmentManager

○ enrollmentId: String

● enrollForCourse (Course c, Student s)

uses

uses

C Course

C Student

Modeling the Dynamic Aspects: Sequence Diagram [Interaction Diagram]

Sequence Diagram

- Captures the dynamic behavior
- Two dimensional-diagram
  - Horizontal: Involved interaction
  - Vertical: Chronological order of the interaction
- Interaction => sequence of event specifications

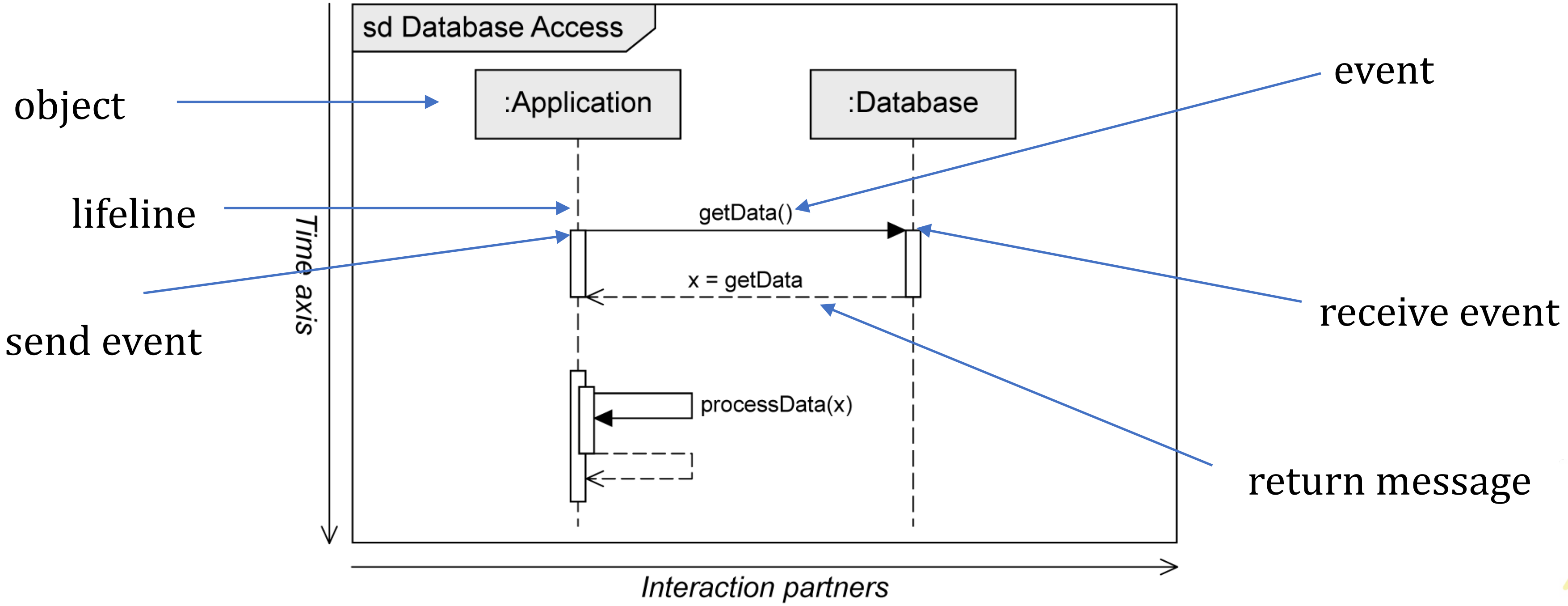
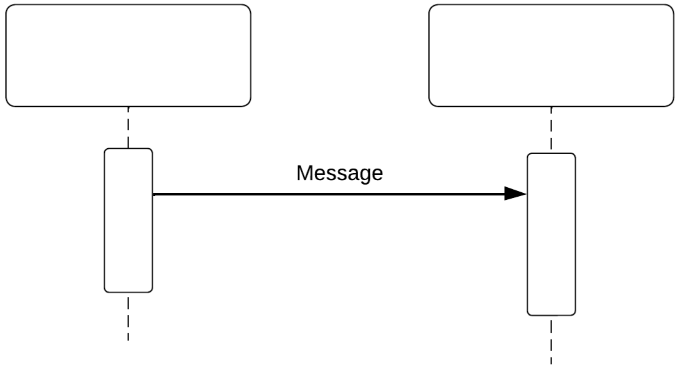


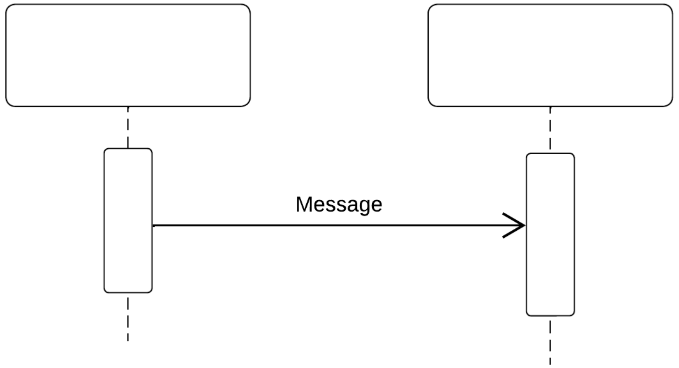
Image source: uml@classroom

Sequence Diagram – Main Message types

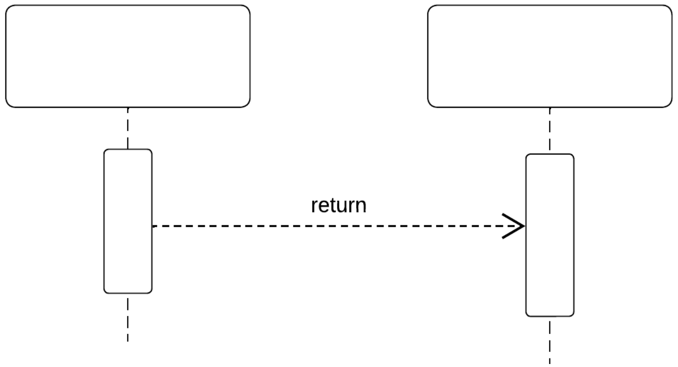
- Synchronous Message
  - Sender waits till the return message is received before next



- Asynchronous Messages
  - Sender does not wait for response message

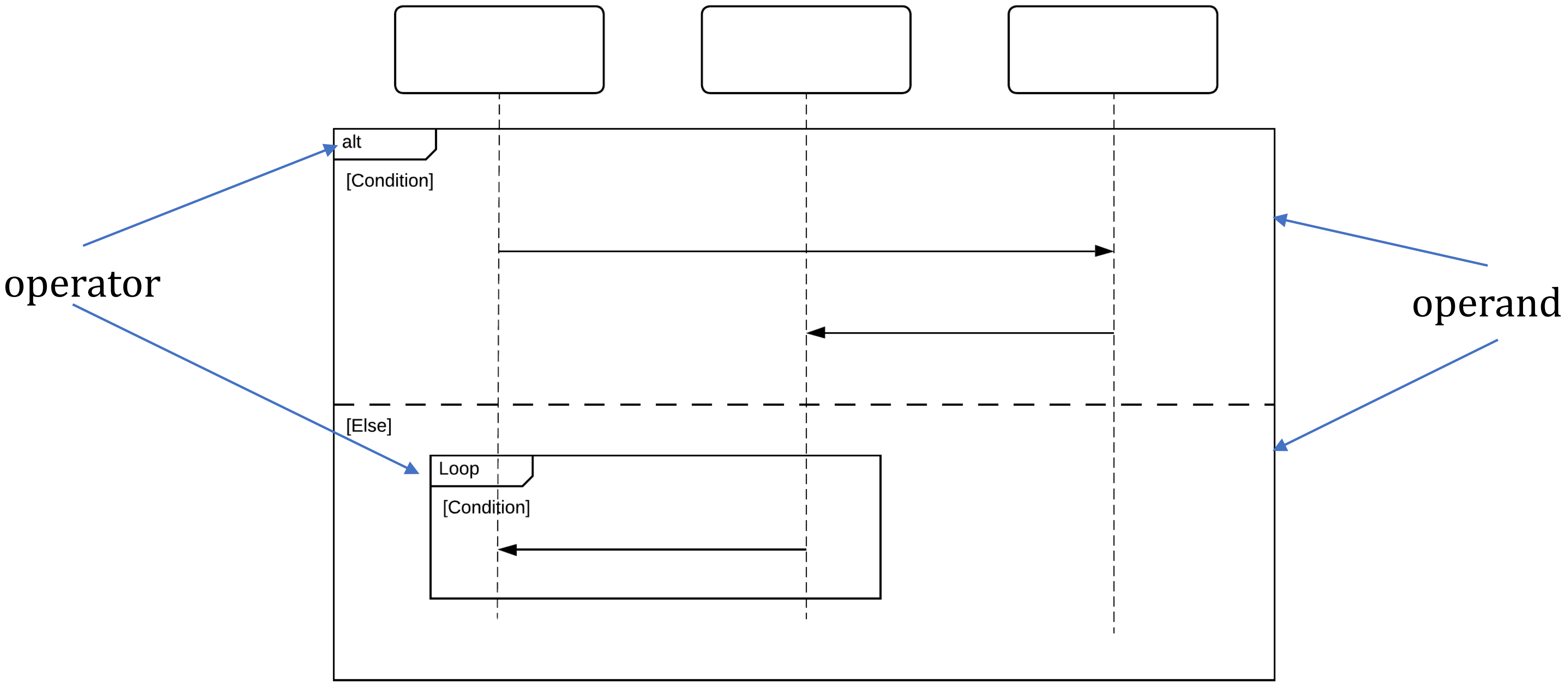


- Response message
  - Not mandatory in obvious situations



Sequence Diagram – Combined Fragments

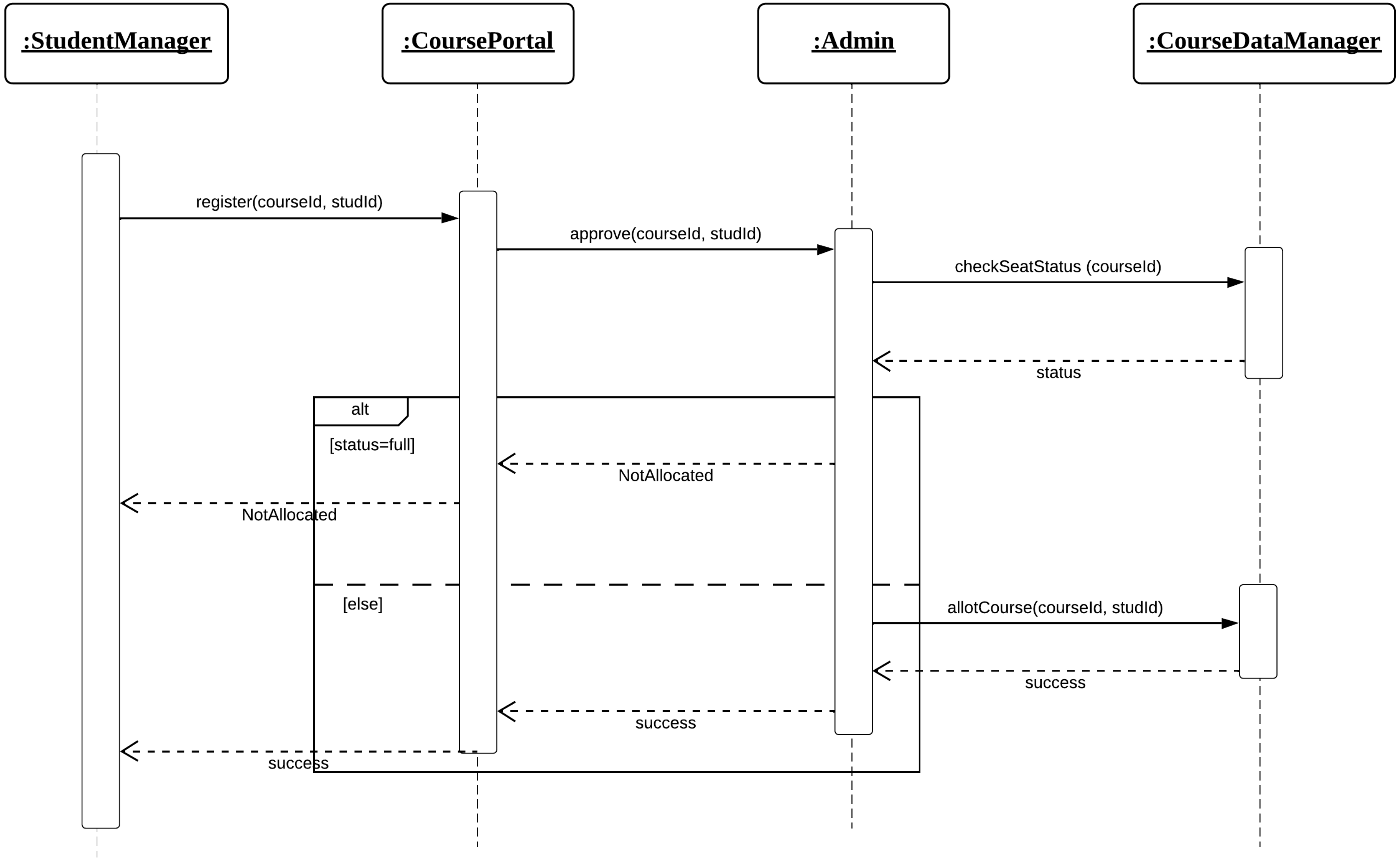
- Model control structures explicitly
- UML sequence diagram supports 12 operators. Three groups
  - Branches and loops, Concurrency and order, Filters and Assertions



Different Operators

Name and Operator	Use
Alternative (alt)	Express alternative execution (if-else)
Optional (opt)	Fragment executes based on guard condition (if)
Break (break)	Execution of a fragment when break condition is met
Loop (loop)	Repeated execution of a fragment
Sequential (seq)	Weak ordering (default model)
Strict (strict)	Interaction with strict order
Parallel (par)	Concurrent execution of sub-scenarios
Critical (critical)	Atomic interactions (no other interactions can affect)
Ignore (ignore)	Irrelevant messages (insignificant messages at runtime)
Consider (consider)	Important messages of the interactions
Negate (neg)	Model invalid interactions, undesirable situations
Assert (assert)	To assert certain interactions (mandatory)

Sequence Diagram – Example



ACTIVITY-1

Smart vehicle booking system for in campus transportation

- Create a **high-level design** of a software system in form of a **UML diagram** to show the overall class structure of the system

- We're looking forward to designing a software system to **book smart bikes for in-campus transportation** at IIIT-H campus. The design must accommodate various kinds of users being able to book smart bikes via a mobile app and make payment. The user must be able to complete onboarding, scan QR code on the bikes parked in the parking lot to start the trip, end the trip and make payment either manually or through auto-deduct facility.

- Refer the pdf posted on moodle for details

Thank You

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