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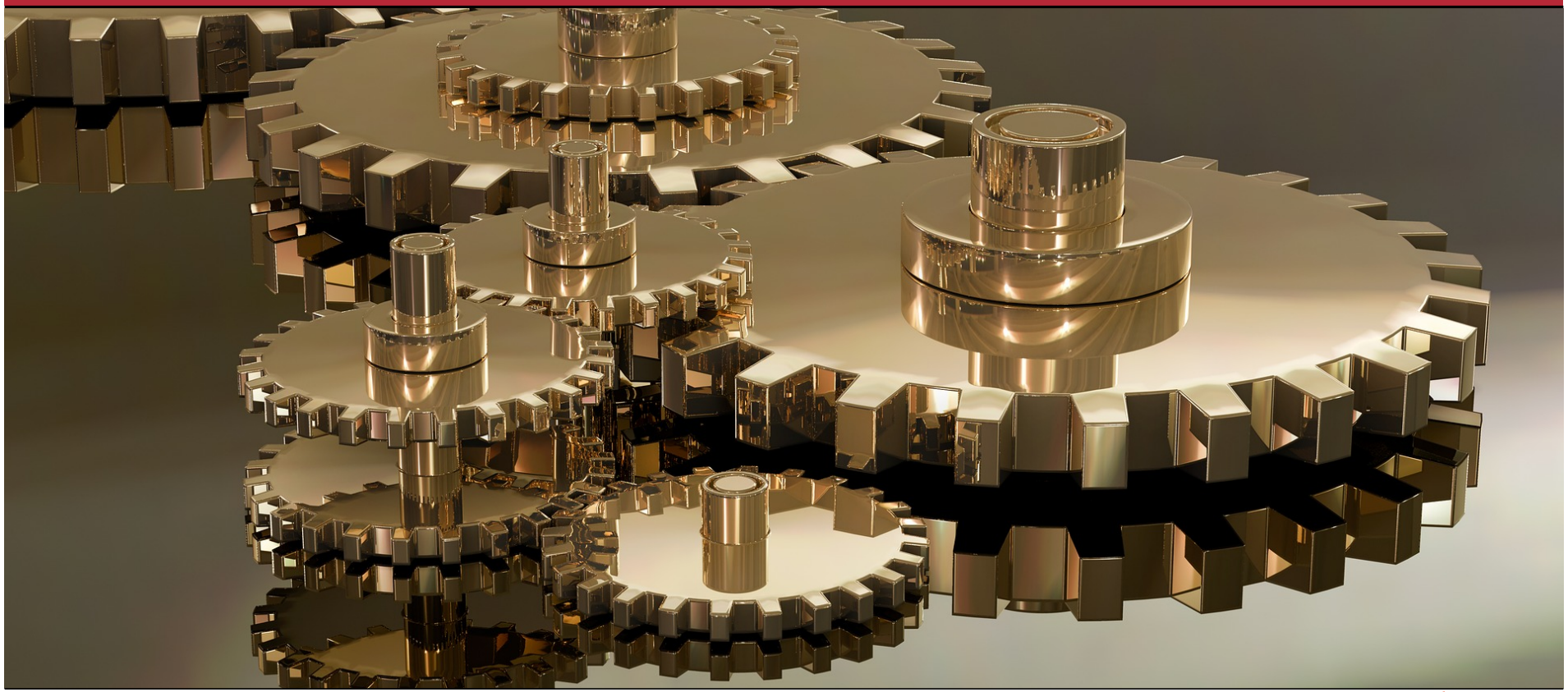
Domain Modelling

Prof. Dr. Reiner Hähnle
Fachgebiet Software Engineering



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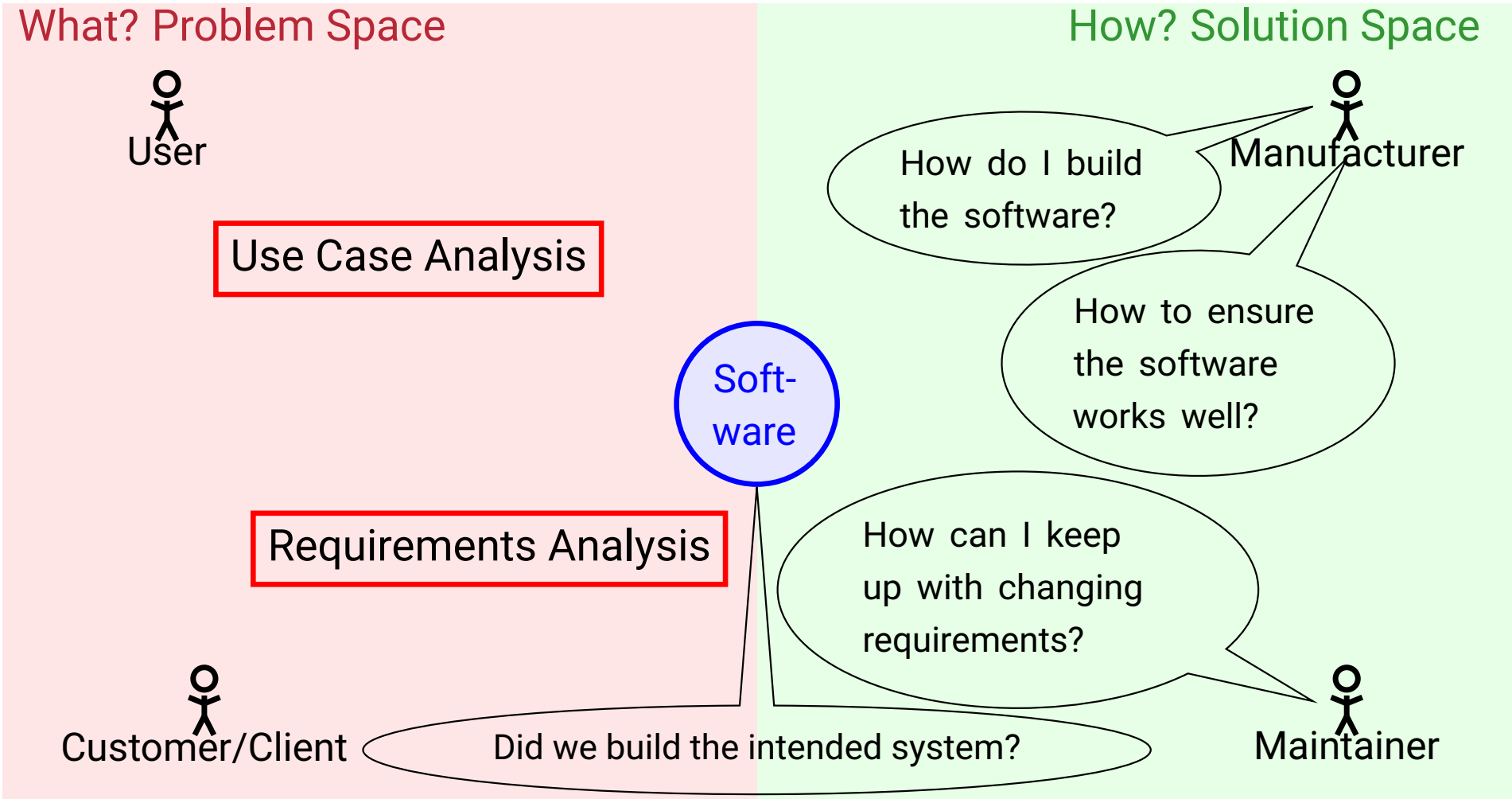

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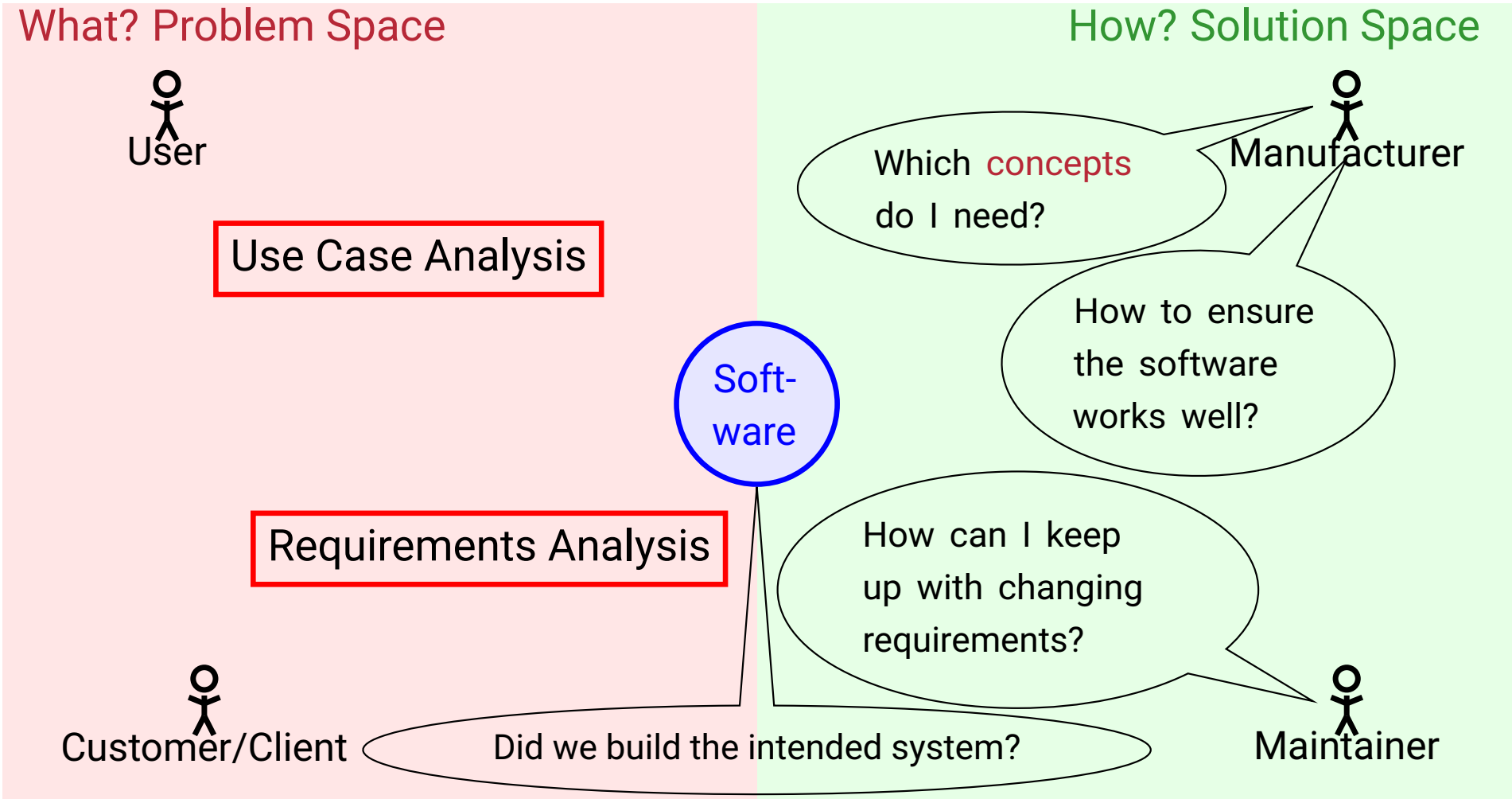

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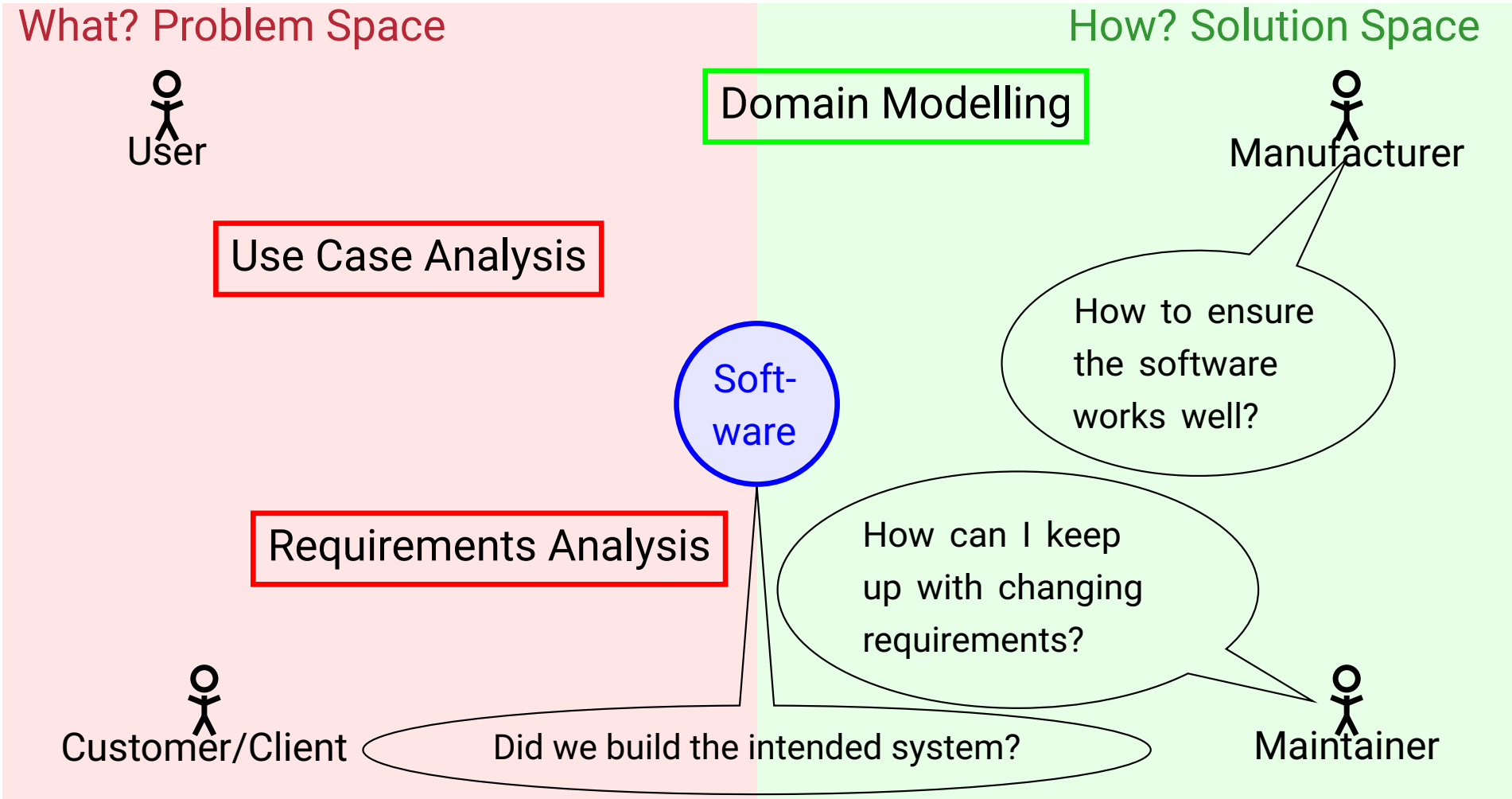

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General Approach: Object-oriented Analysis & Design

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In the solution space we use Object-oriented Analysis & Design (OOAD)

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General Approach: Object-oriented Analysis & Design

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In the solution space we use Object-oriented Analysis & Design (OOAD)

Motivation

- Considered state-of-art
- Widely-used in industrial practice, many software processes
- Numerous training resources available
- Compatible with wide-spread visual modeling notation UML
- Compatible with C++, C#, JAVA, KOTLIN, SCALA, ...

Domain Modelling

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Domain Modelling

Fixing the terminology and fundamental activities of the solution space

Why: Helps to identify the relevant concepts and tasks of a domain

Prerequisite: Requirements analysis and use case analysis are done

Context: Part of object-oriented analysis (OOA)

Heuristics: Only performed for the tasks at hand

Curtis' law: "...good designs require deep application knowledge."

— A. Endres & D. Rombach, A Handbook of Software and Systems Engineering

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Domain model must be validated with Client

Domain Model

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Goal of an Object-Oriented Domain Model

Decompose the domain into concepts or objects that represent the real world (as captured in the requirements specification)

How to create an Object-Oriented Domain Model

- Identify the set of conceptual classes and fundamental actions

Iteratively completed and forms the basis for the software design

Domain Model

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Synonyms for Domain Model

- Conceptual model, domain object model, analysis object model
  “Konzeptmodell”, “Analysemodell”

Conceptual Classes

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Definition (Conceptual class “Konzeptklasse”)

Conceptual classes represent ideas, things or objects in the domain.
A conceptual class has

- a name or symbol representing the class,
- an intention (“Bedeutung”),
- an extension (“Ausprägung”, “Extension”).

The extension contains the domain elements the conceptual class represents.

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The extension contains the domain elements the conceptual class represents.

Domain concepts/conceptual classes are not software objects –
They derive from the problem space

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Part II

UML Class Diagrams as Conceptual Models

Visualization of Domain Models

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Domain models are visualized using UML class diagrams

But with suitable restrictions to emphasize domain modelling:

- Only domain objects and conceptual classes
- Only associations, no aggregation, no composition
- Classes may have attributes (used sparingly), but no operations

UML class diagram of domain model is called conceptual perspective model
"Modell der Konzeptperspektive"

Example: CaSh Booking System

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- Bookings are made by customers
- Customers must have an authentication to make a booking
- Each booking is for exactly one car
- The monthly bill comprises all completed and unpaid bookings
- Each booking is for a duration of between 30 minutes and four weeks
- A customer cannot have more than three active bookings
- Each car needs to have a regular service carried out by a service person

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Example: CaSh Booking System

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Booking

Customer

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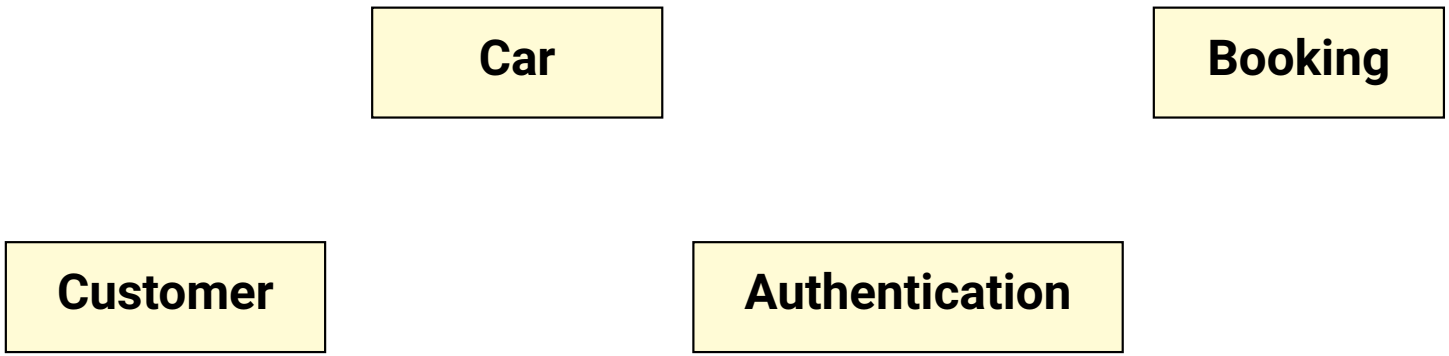

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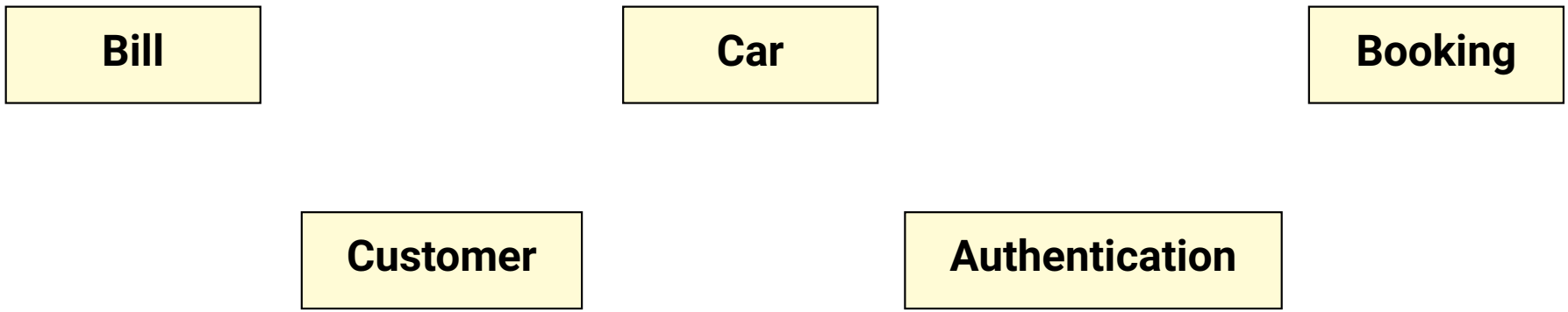

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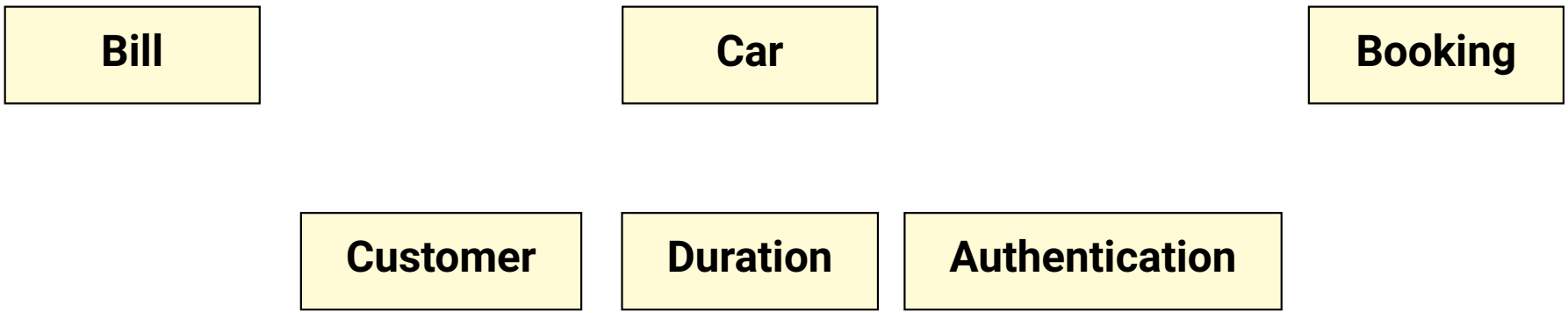

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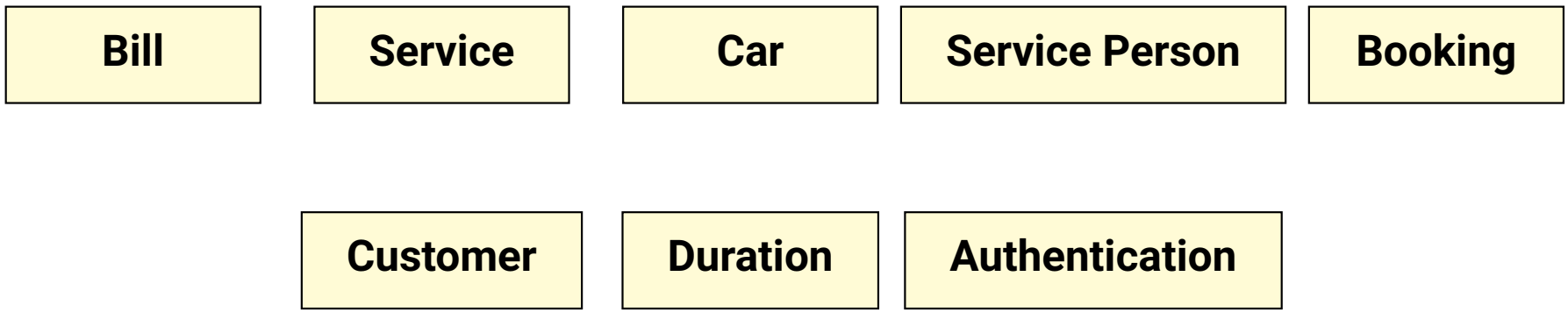

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Extracting a First Class Model

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Bill | **Service** | **Car** | **Service Person** | **Booking**

Customer | **Duration** | **Authentication**

Classes

A (conceptual) class describes a set of (domain) objects

An object is an individual thing with a state and relations to other objects

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Properties of Conceptual Classes: Attributes

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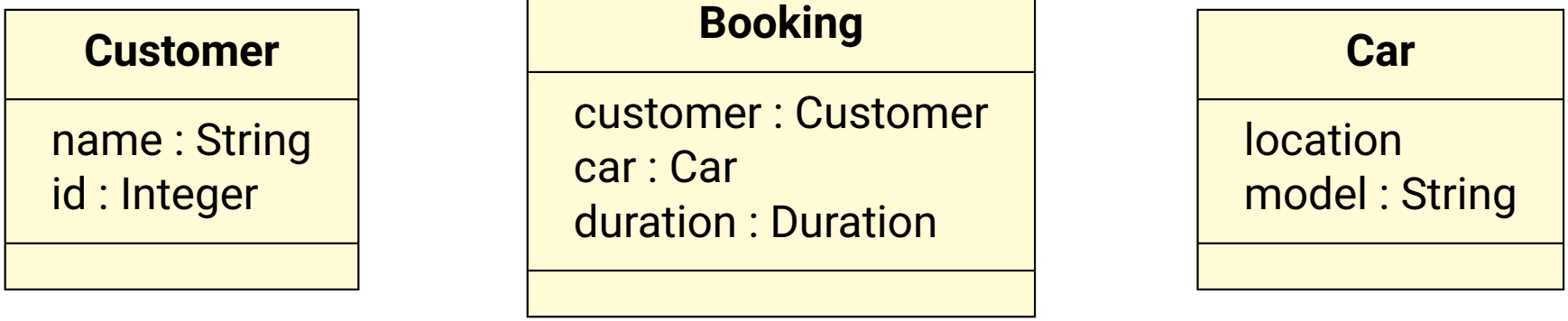

Attributes:

- Logical data values of an object (class instance, domain element)

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Properties of Conceptual Classes: Attributes

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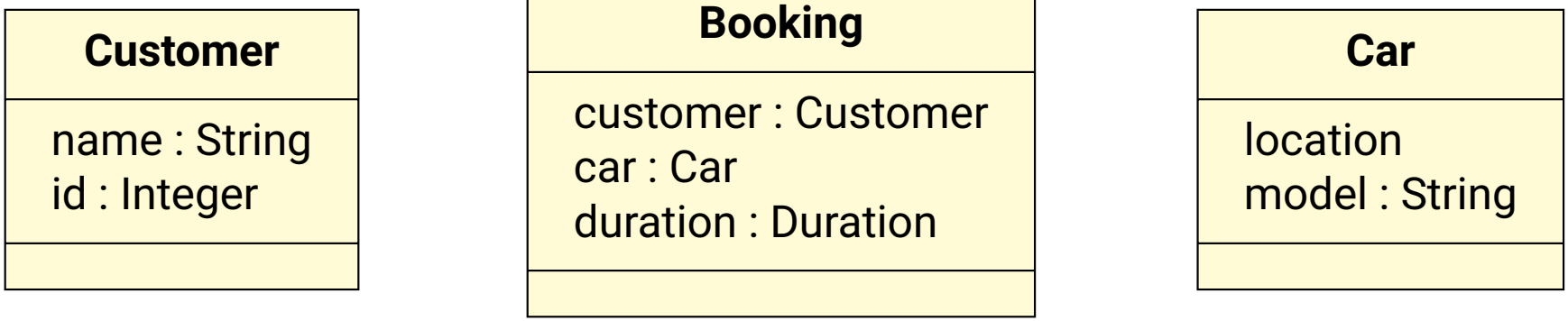

model(aCar)=“Opel Corsa”

Attributes:

- Logical data values of an object (class instance, domain element)
- Map objects of the containing class to objects of their target type

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Properties of Conceptual Classes: Attributes

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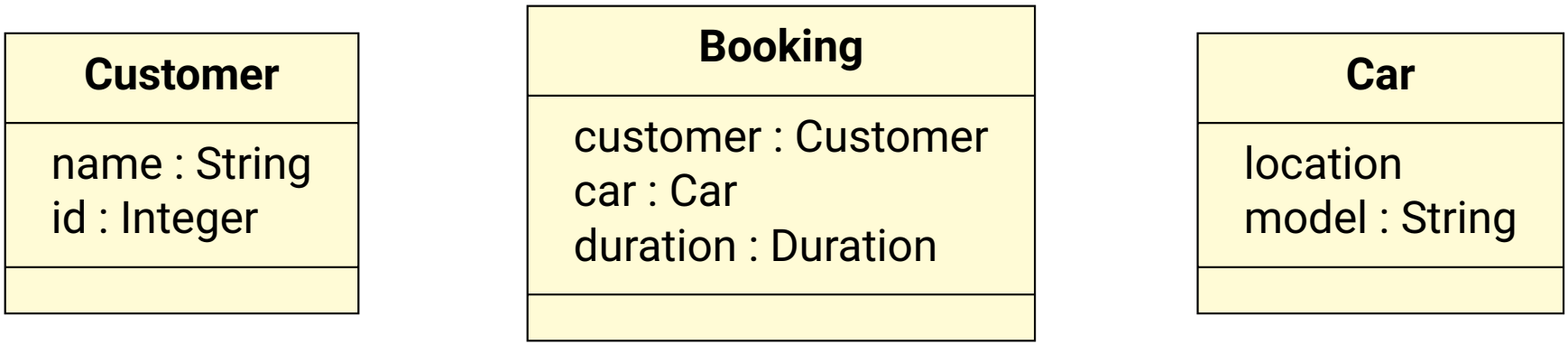

Attributes:

- Logical data values of an object (class instance, domain element)
- Map objects of the containing class to objects of their target type

During domain modelling:

- Identify attributes of conceptual classes needed to satisfy information requirements
- Limit number of attributes to scope of treated scenarios

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UML Model Element Class: Simplified Syntax for Domain Modelling

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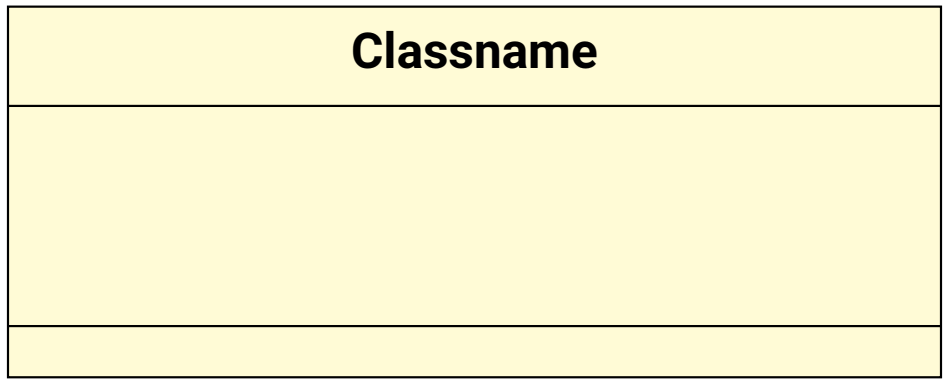

UML Class Elements and Conventions

Class Name Class names start always with an upper case letter

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UML Model Element Class: Simplified Syntax for Domain Modelling

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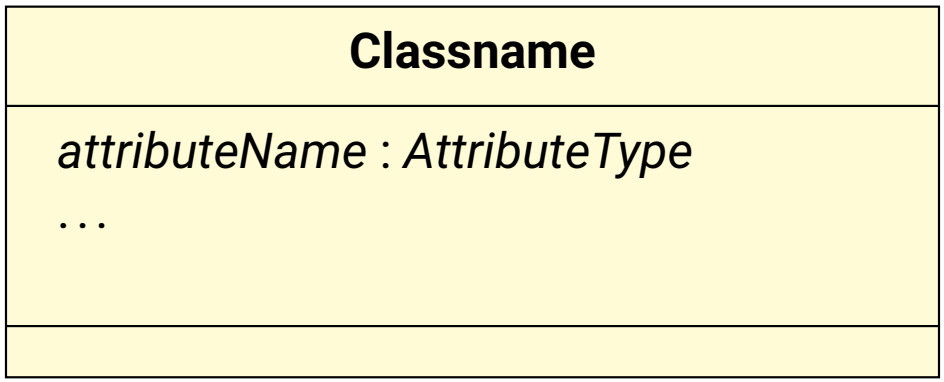

UML Class Elements and Conventions

Class Name Class names start always with an upper case letter

Attribute Attribute name: starts with a lower case letter
Attribute type: pre-defined type or other domain model class
(type can be omitted in domain modelling)

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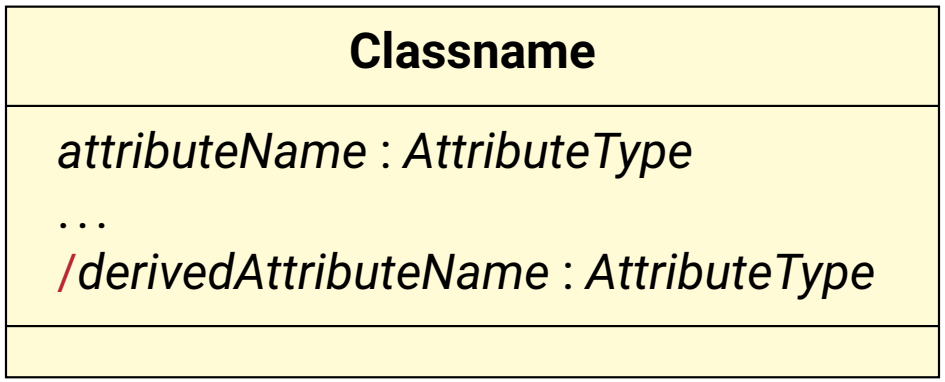

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Attribute Attribute name: starts with a lower case letter
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Derived Attribute: name prefixed by a slash (’/’)
Value computable from existing information

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Example: Derived Attribute

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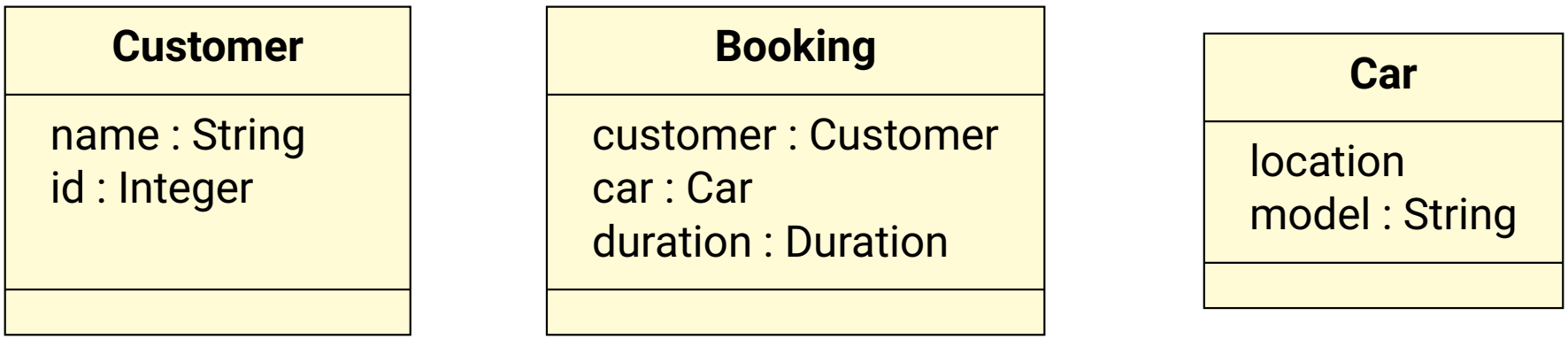

Example (Active Bookings)

- The active bookings of a customer are all not yet completed bookings

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Example: Derived Attribute

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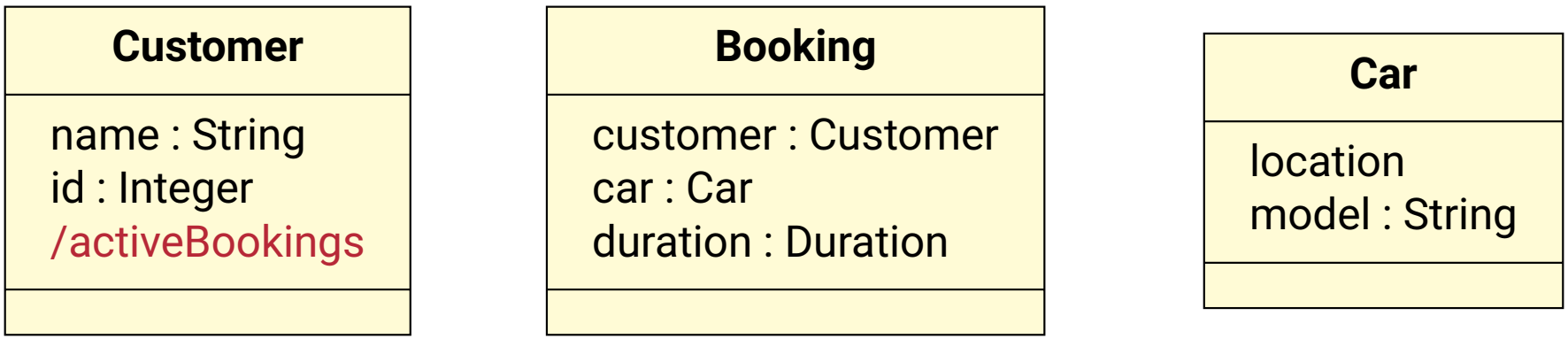

Example (Active Bookings)

- The active bookings of a customer are all not yet completed bookings

The active bookings for a customer can be computed:
Collect all bookings of the customer whose end time is not past the current time
Derived attributes are usually not assigned values independently

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CaSh Booking System: Associations (Relations)

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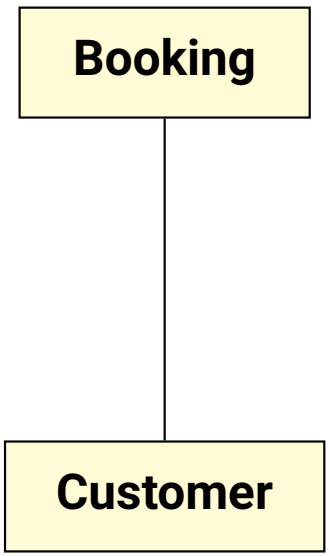
- Bookings are made by customers

CaSh Booking System: Associations (Relations)



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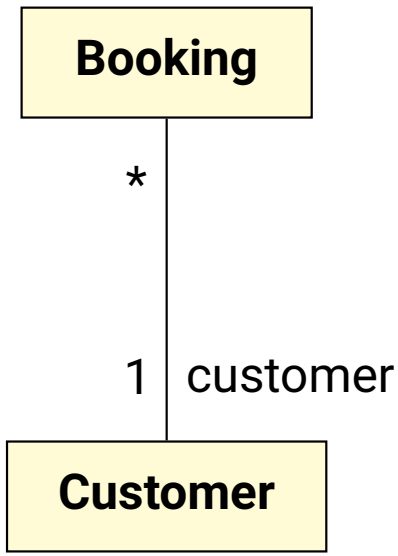

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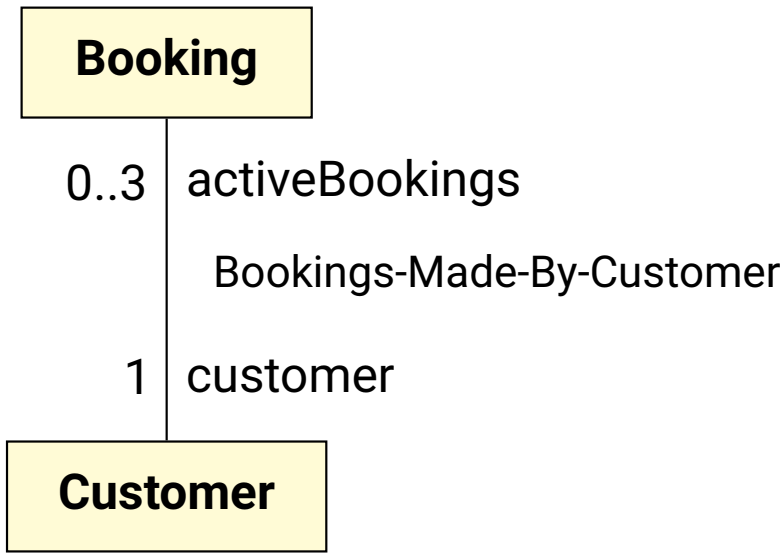

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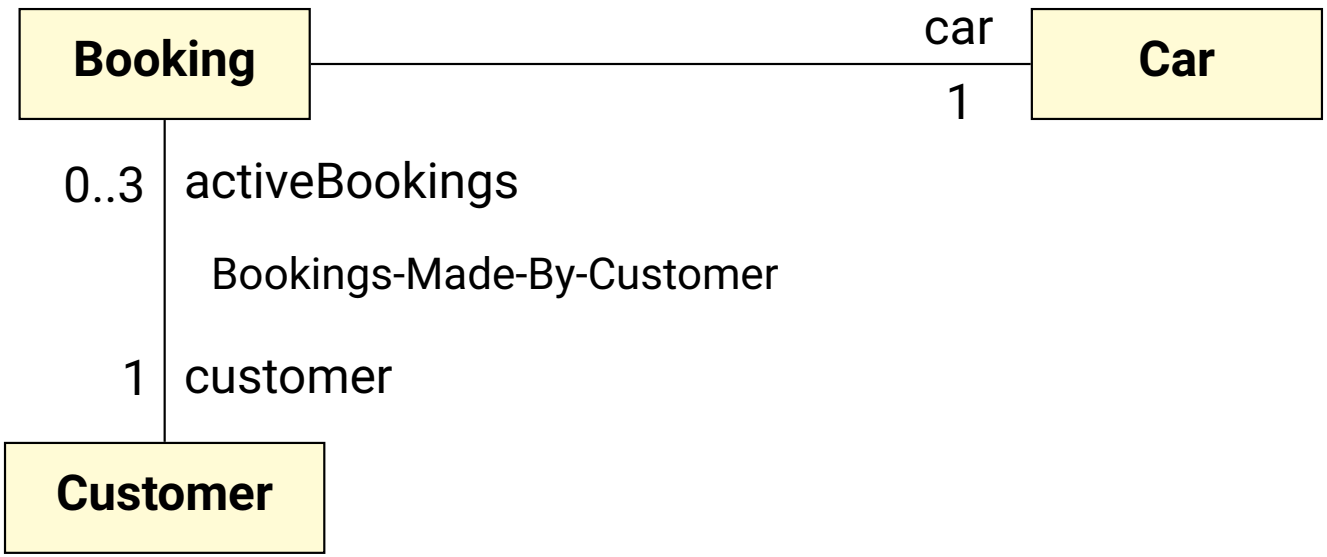

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CaSh Booking System: Associations (Relations)

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- Bookings are made by customers
- A customer cannot have more than three active bookings
- Each booking is for exactly one car
- A car may appear in an arbitrary number of bookings

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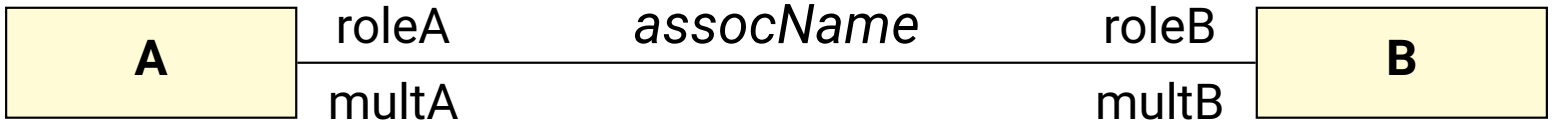
Syntax of UML Association



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    Possible multiplicities: $*$ or $a..b$
    a, b are value specifications (numbers expressions); upper bound incl. $*$

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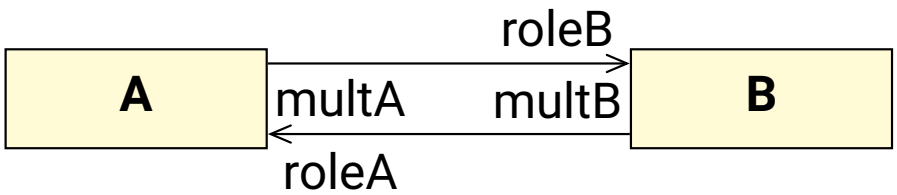
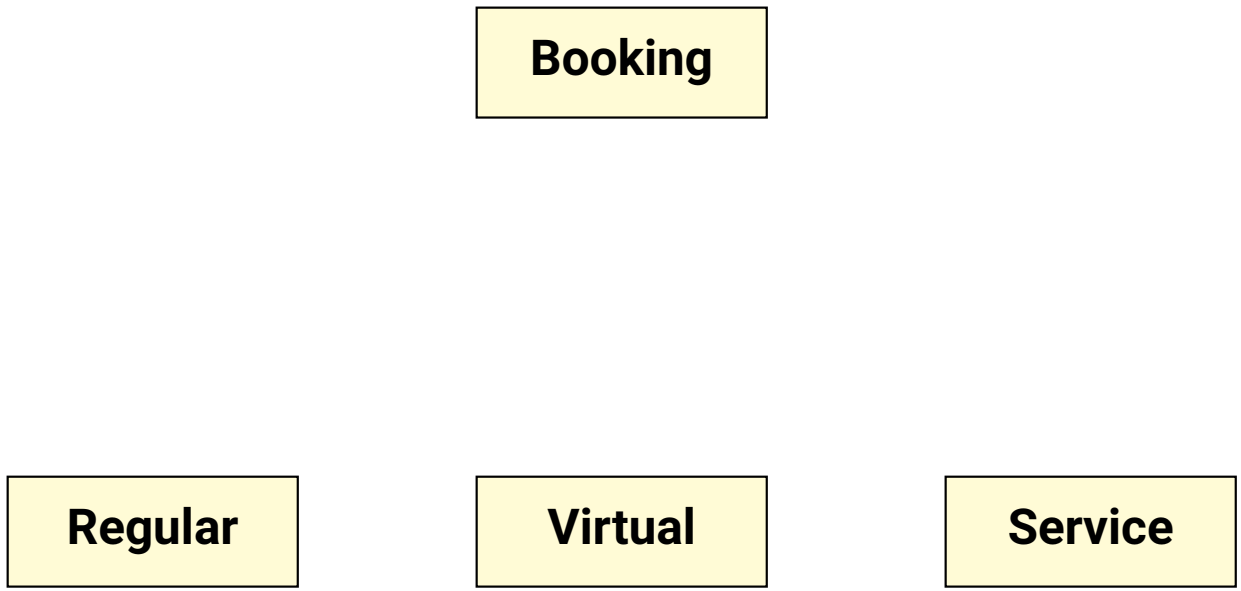
    a, *b* are value specifications (numbers expressions); upper bound incl. $*$
  - A navigability (defaults to bi-directional, not used for conceptual classes)

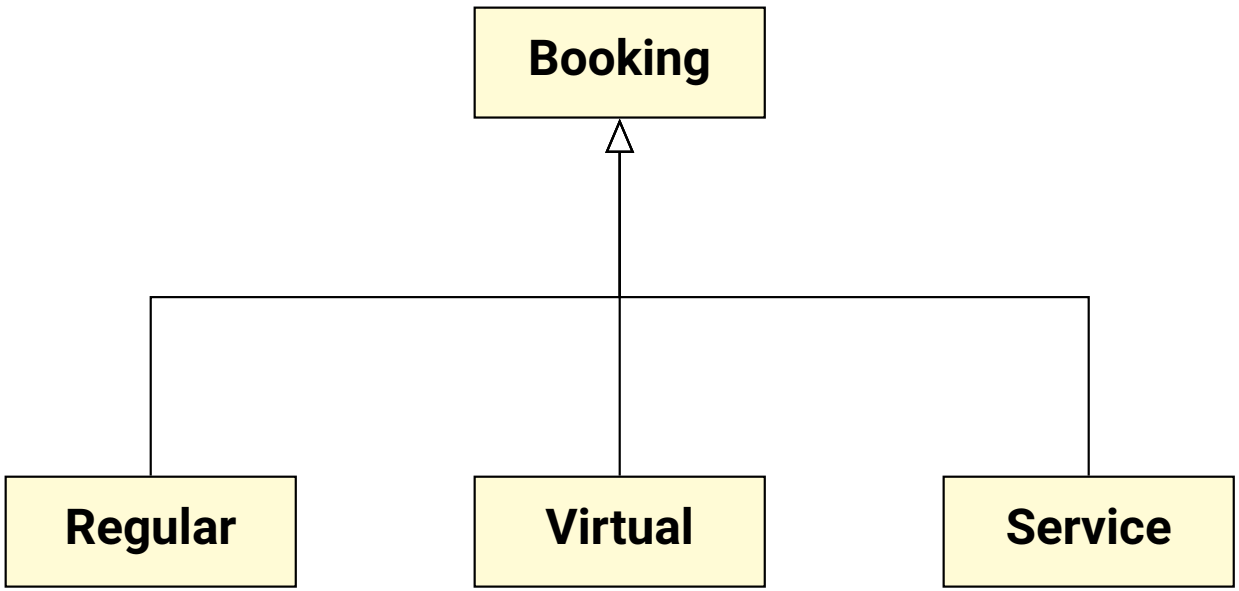


Generalizations of Concepts



- There are different types of bookings: regular, virtual , service

Generalizations of Concepts



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Elicitation of Domain Model for a New Domain: Workflow

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1. Find the conceptual classes

   Possible Strategies:

   - Re-use or modify an existing model
   - Use a category list
   - Identify noun phrases
2. Draw elicited concepts as classes in a UML class diagram
3. Add attributes
4. Add associations

Use the domain vocabulary:
The CaSh model should use names like Customer instead of Person

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Re-using an Existing Model

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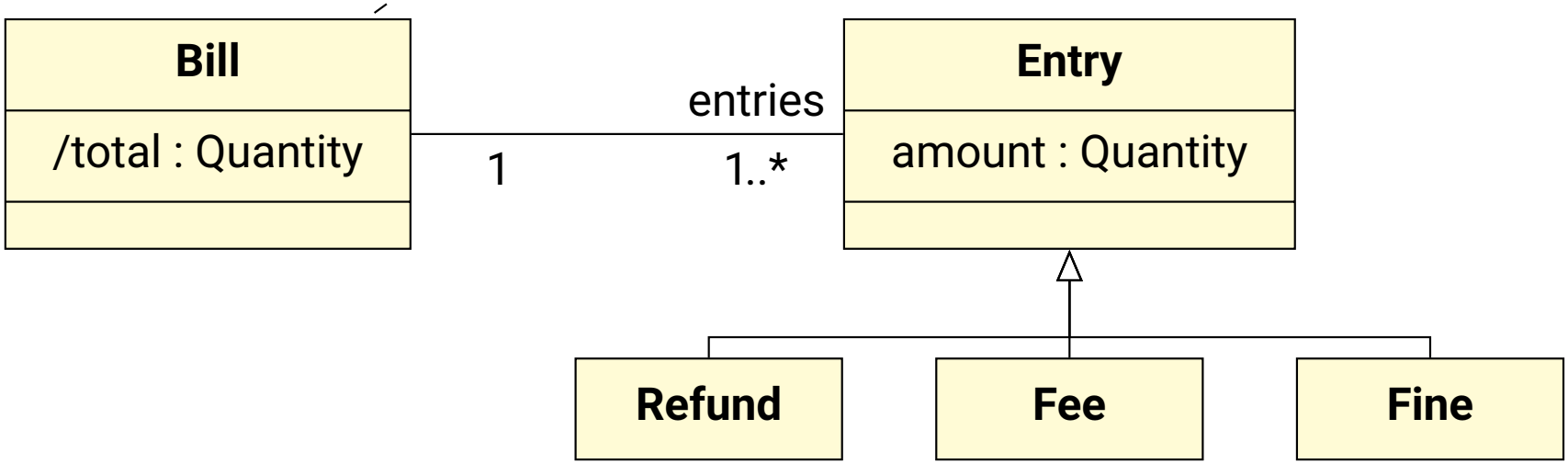
for any object self of type **Bill**: $\text{self.total} = \sum_{s \in \text{self.entries}} s.\text{amount}$

[[in OCL: self.total = self.entries -> collect(s | s.amount) -> sum()]]



(For example: M. Fowler. Analysis Patterns—Reusable Object Models, Addison-Wesley, 1997)

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Conceptual Class Discovery Technique: List of Conceptual Class Categories

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Some Categories:

- Physical or tangible objects
- Specifications or description of things
- Locations
- Events
- Transactions
- Transaction items
- Organizations
- Roles (of people, organizations, etc.)
- Containers
- . . .

Using a Category: Example

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Conceptual Class Category

Conceptual Classes (in CaSh)

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Using a Category: Example

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Conceptual Class Category	Conceptual Classes (in CaSh)
Business transaction	Bill, Payment
Transaction line item	Entry
Product or service related to a transaction or to a transaction line item	Refund, Rent, Fine
Place where transaction is recorded	Registry
Roles of people or organizations related to a transaction (actors in use cases)	Customer, Accountant
Location where transaction executed	Website
Noteworthy events, with a time or place that needs to be remembered	Bill, Booking

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Conceptual Class Discovery Technique: Noun Identification

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Workflow

- Identify nouns and noun phrases in textual descriptions of domain
- Consider them as a candidate for a conceptual class or an attribute

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Can it be automated?

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Can it be automated?

Only partially: Words in natural language texts are ambiguous

- Same noun can mean multiple things
- Different nouns can mean the same thing

LLMs might be helpful, but need to validate

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Use Cases (stories) are a canonical source for identifying conceptual classes

Example:
Noun Identification

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Text Story: Change Existing Booking

The customer selects the booking to change. The system displays the booking details, including adjacent reservations. The customer is offered to change the reserved duration. When a new duration is entered, the system checks availability and records the change. In case of no availability, nothing happens and an information message is displayed. Before any change happens, a confirmation action is requested. Afterwards, a confirmation message is sent to the customer's preferred contact.

Example:
Noun Identification

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Example: Noun Identification

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Text Story: Change Existing Booking

The customer selects the booking to change. The system displays the booking details, including adjacent reservations. The customer is offered to change the reserved duration. When a new duration is entered, the system checks availability and records the change. In case of no availability, nothing happens and an information message is displayed. Before any change happens, a confirmation action is requested. Afterwards, a confirmation message is sent to the customer's preferred contact.

Candidate Conceptual Classes

Customer, Booking, Detail, Reservation, Duration, System, Availability, Change, InformationMessage, ConfirmationAction, ConfirmationMessage, Contact

Selection of Suitable Conceptual Classes

Which nouns should become conceptual classes in domain model?

Example: Should ConfirmationMessage be a conceptual class?

Selection of Suitable Conceptual Classes

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Criteria to include a candidate conceptual class:

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  Avoid candidates that add only
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Conclusion: Confirmation Message is report about a booking

Boundary of Domain Model

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Report: Part of the domain model? — It depends!

Boundary of Domain Model

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Boundary of Domain Model

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In general:
Regarding legal aspects . . . ? ⟵ Non-functional domain requirement (lecture 2)

More In-/Exclusion Criteria for Conceptual Classes

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Candidate Conceptual Classes

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6. Synonym of changed Booking

⋮

Description Classes

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A description class contains information that describes an entity

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- A rental location description has information on:
  Address, accessibility, closest public transport, etc.

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3. Redundant or duplicated information is reduced

Model a Notion as Class or Attribute?

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Heuristics: Class or Attribute

If we do not think of a notion *C* as a number, text or data of the real world, then *C* is probably a conceptual class, not an attribute

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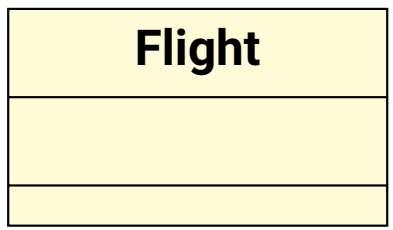
Example (Airport)



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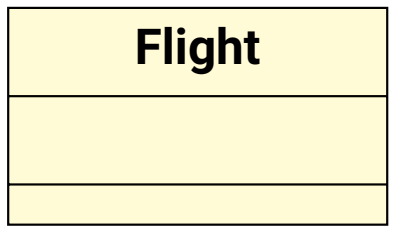

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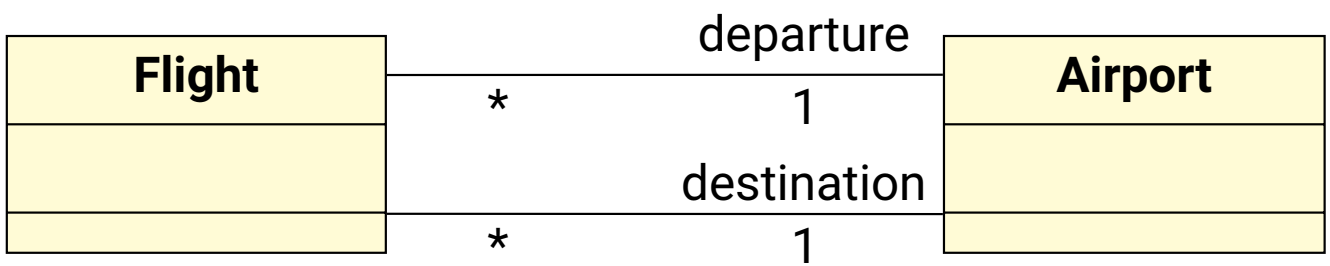

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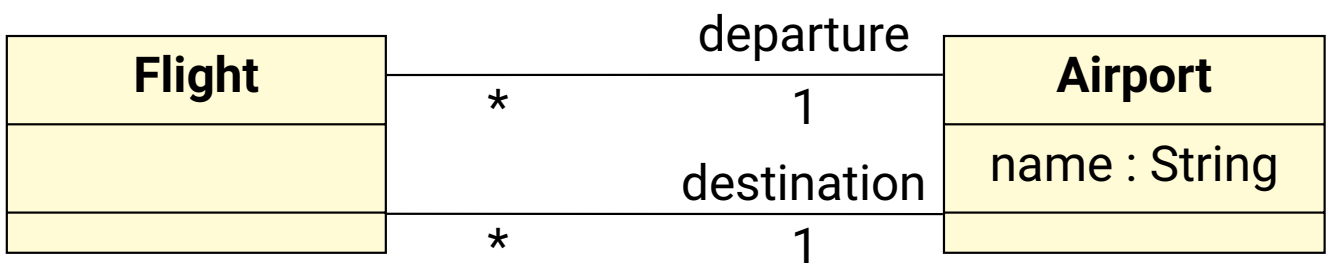

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Use of Associations in Domain Modelling

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Heuristics

Include associations in the domain model when:
Knowledge about the relation needs to be preserved for some time

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Use of Associations in Domain Modelling

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Heuristics

Include associations in the domain model when:
Knowledge about the relation needs to be preserved for some time

Example

The relation between a bill and its entries needs to be remembered

But it is unnecessary to store the relation
between a customer and his or her most recent search for available cars

On the other hand, a browser might well record the search history

Use of Associations in Domain Modelling

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Heuristics

Include associations in the domain model when:
Knowledge about the relation needs to be preserved for some time

List of common association categories:

- *A* is a transaction related to another transaction *B*
- *A* is a product or a service for a transaction *B*
- *A* is a role related to a transaction *B*
- *A* is a physical or logical part of *B*
  For example, *A* is a line item of a transaction *B*

Association Name

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Name an association based on a Class name-Verb phrase-Class name format

The verb phrase creates a sequence that is readable and meaningful

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Good examples:

- Player-Stands-on-Square
- Sale-Paid-by-CashPayment

Association Name

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Name an association based on a Class name-Verb phrase-Class name format

The verb phrase creates a sequence that is readable and meaningful

Good examples:

- Player-Stands-on-Square
- Sale-Paid-by-CashPayment

Bad examples:

- Player-Has-Square (“Has” is generic, doesn’t tell about relation)
- Sale-Uses-CashPayment (“Uses” dito)

Attribute or Association?

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A property can be modelled as an association or an attribute

The notations are very different! — When to use what?

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Attribute or Association?

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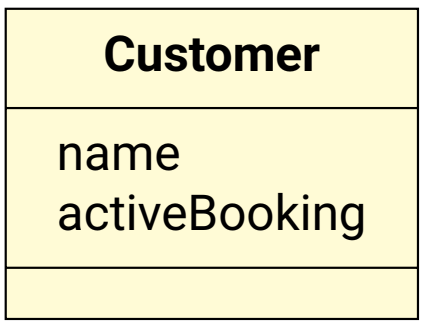

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Attribute or Association?

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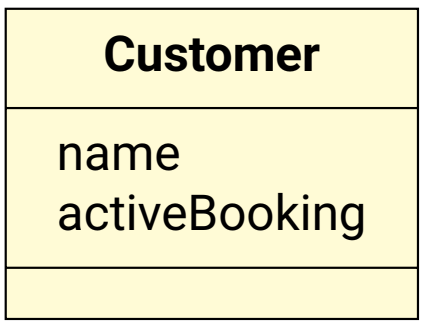
- Attributes should always be used for primitive datatypes
  - Boolean, Integer, Character, String
  - Date, Address, Color, Phone Number, . . .



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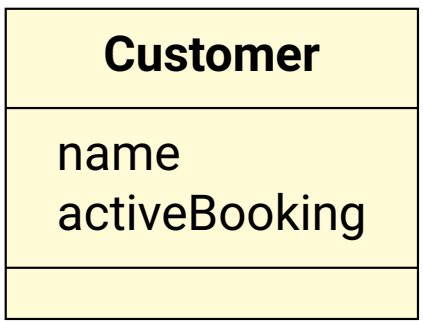
  - currency (EUR, USD, SEK, . . .)
  - weight (kilogram, cm, . . .)



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  - currency (EUR, USD, SEK, . . .)
  - weight (kilogram, cm, . . .)
- Always use associations to model relations between conceptual classes

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Refining a Model: Replace String Type

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It is convenient to type attributes initially with String:

Generic type that avoids premature decision

Later, consider refinement to description class

Car
model : String

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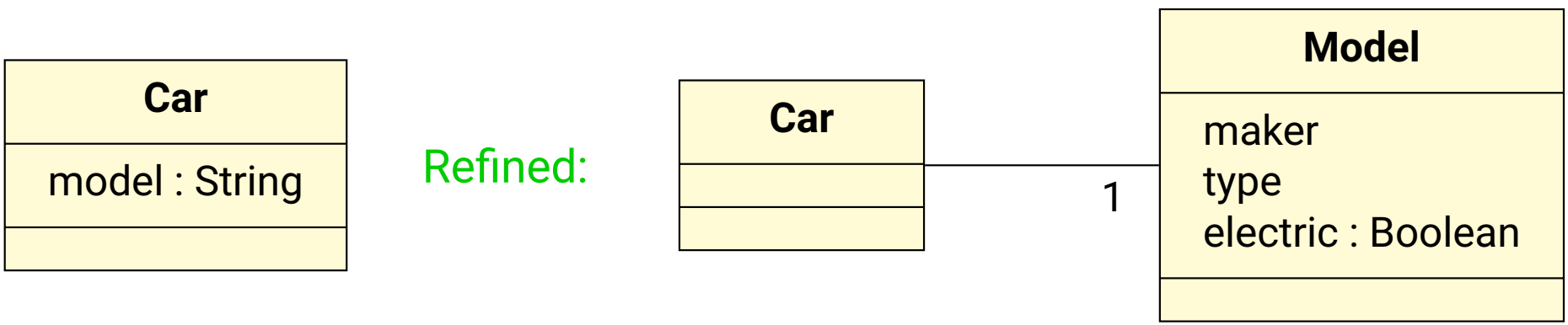

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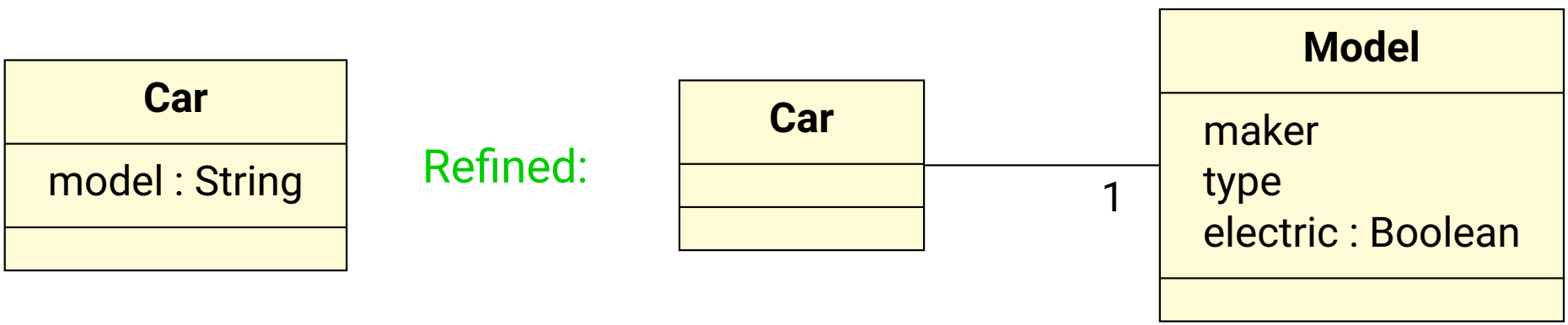

- When string has structure, i.e. composed of separate sections: Maker, type
- When other relations are associated with the string: social security nr
- When the string has other attributes: electric
- When the string is a quantity with a unit, for example, a currency

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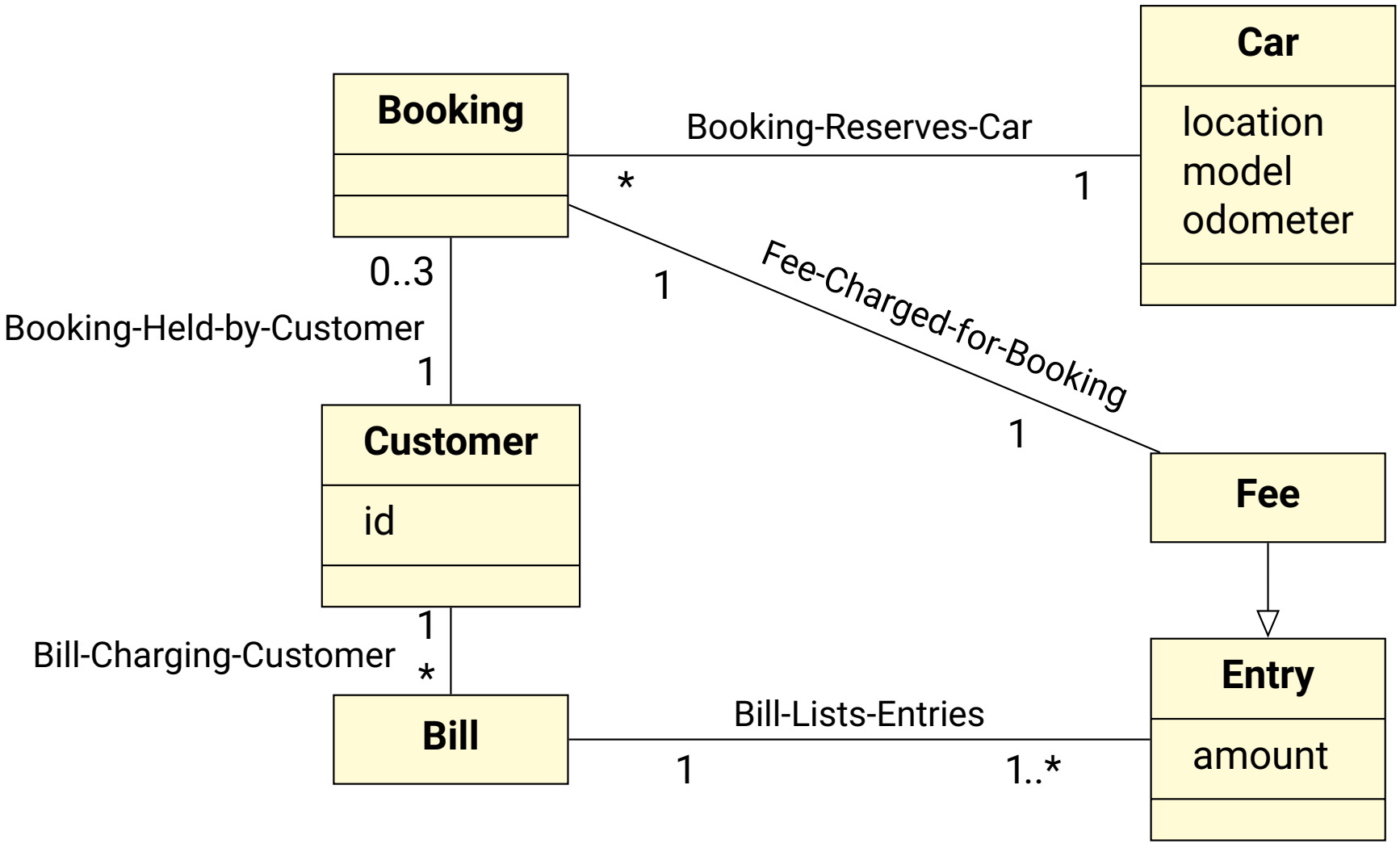
CaSh Booking System: Domain Model (Excerpt)



From Domain Model to Design Model

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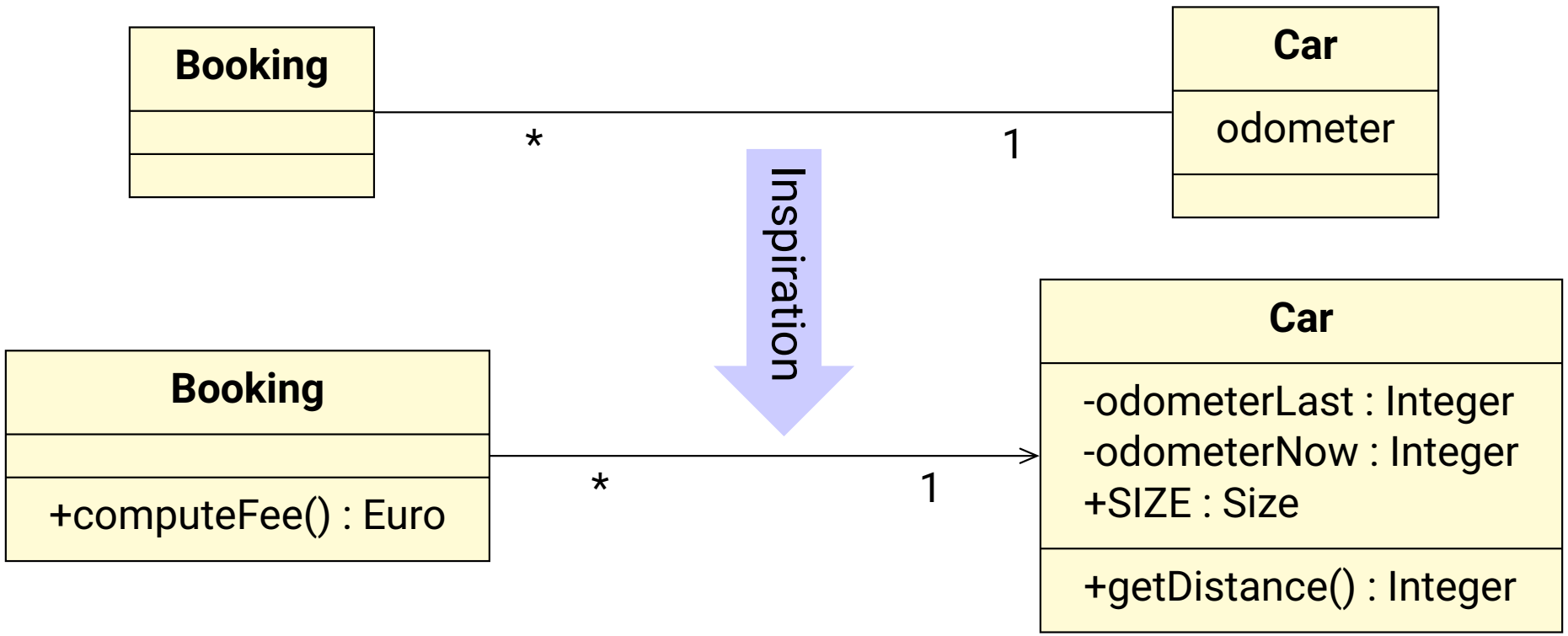
The domain model serves as a source of inspiration for the design model



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Domain Model is Not Static View on Code

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The Two Faces of UML Class Diagrams

1. Conceptual perspective model in domain modelling (our usage)
2. Static view (classes, methods, fields) extracted from OO code

Don’t confuse them, for example, abuse the former as code stubs

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Part III

UML State Machine Diagrams as Behavioral Models

Behavioral Domain Modelling

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Class diagrams as conceptual classes model static aspects of a domain

- Conceptual classes, domain elements
- Properties: attributes, associations
- (Functions)

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Behavioral Domain Modelling

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Class diagrams as conceptual classes model static aspects of a domain

- Conceptual classes, domain elements
- Properties: attributes, associations
- (Functions)

What about behavior, such as scenarios?

- Sequences of actions and how they change the
  - state of a system
  - under which condition

UML State Machine Diagrams

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UML State Machine Diagrams are finite state machines
whose transitions are equipped with in-/output actions and guards

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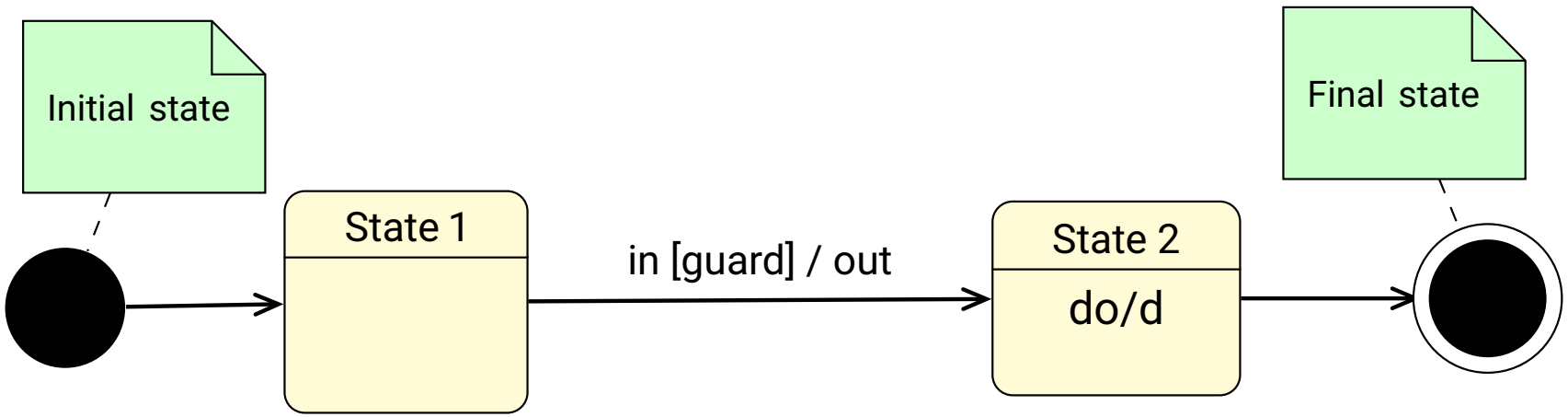

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UML State Machine Diagrams

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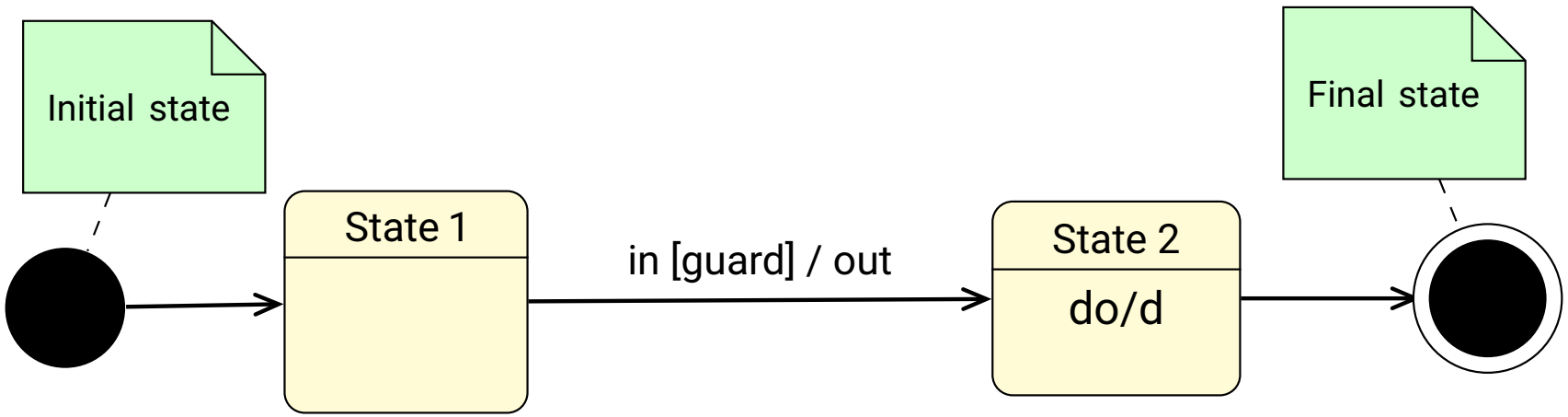

Semantics

When in State 1, if input in is observed and guard is true,
then output out happens and current state becomes State 2.
In State 2 perform (interruptible) action d.

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Basic States

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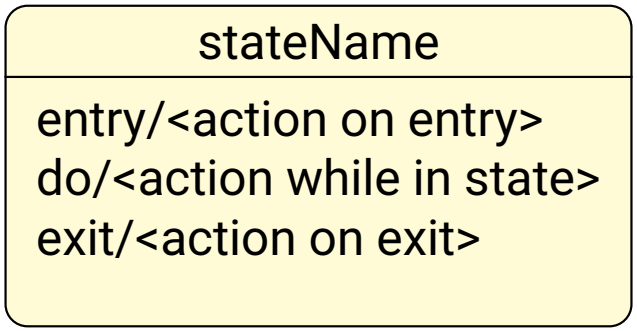


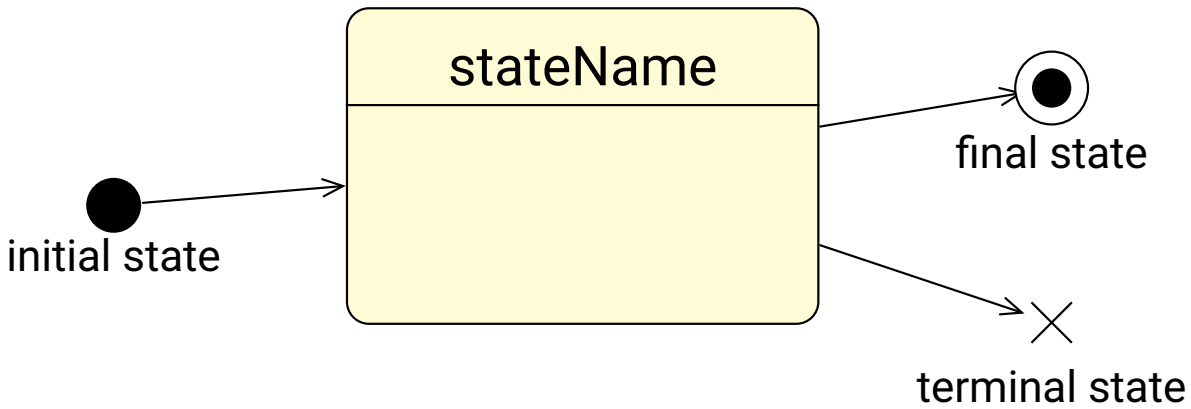
Basic States in Detail

- Basic states have a name and can define any combination of

entry action	action performed on state entry
do action	action performed while in state (until the action terminates or the state is left)
exit action	action performed on state exit

- Actions are executed operations

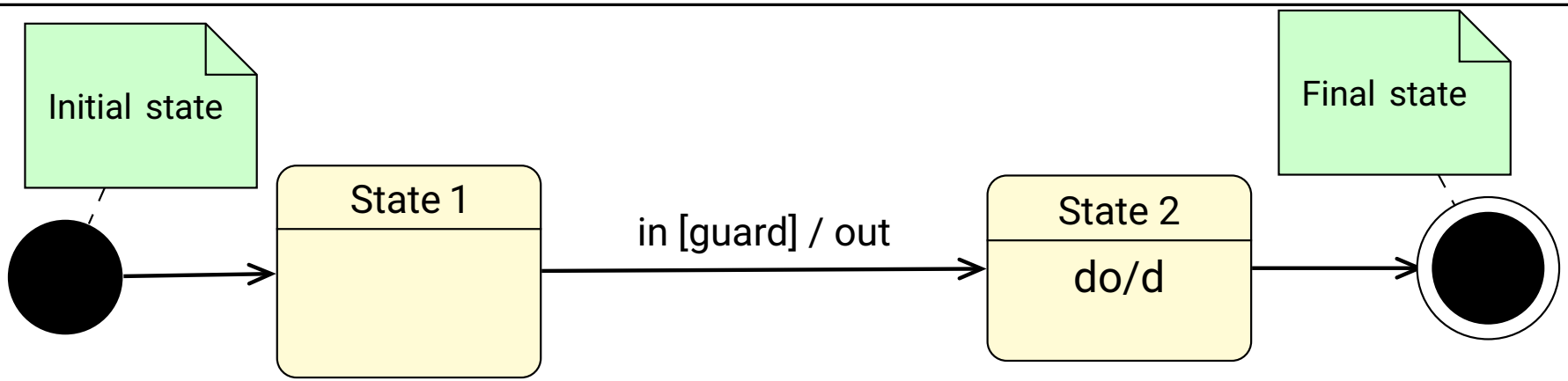
Basic States: Initial, Final & Terminal States



States with Special Meaning

Initial state	has single transition to first entered state (may be labeled by object creation event/message)
Final state	indicates completion of a scenario
Terminal state	completion and executing object destroyed

Transitions between States

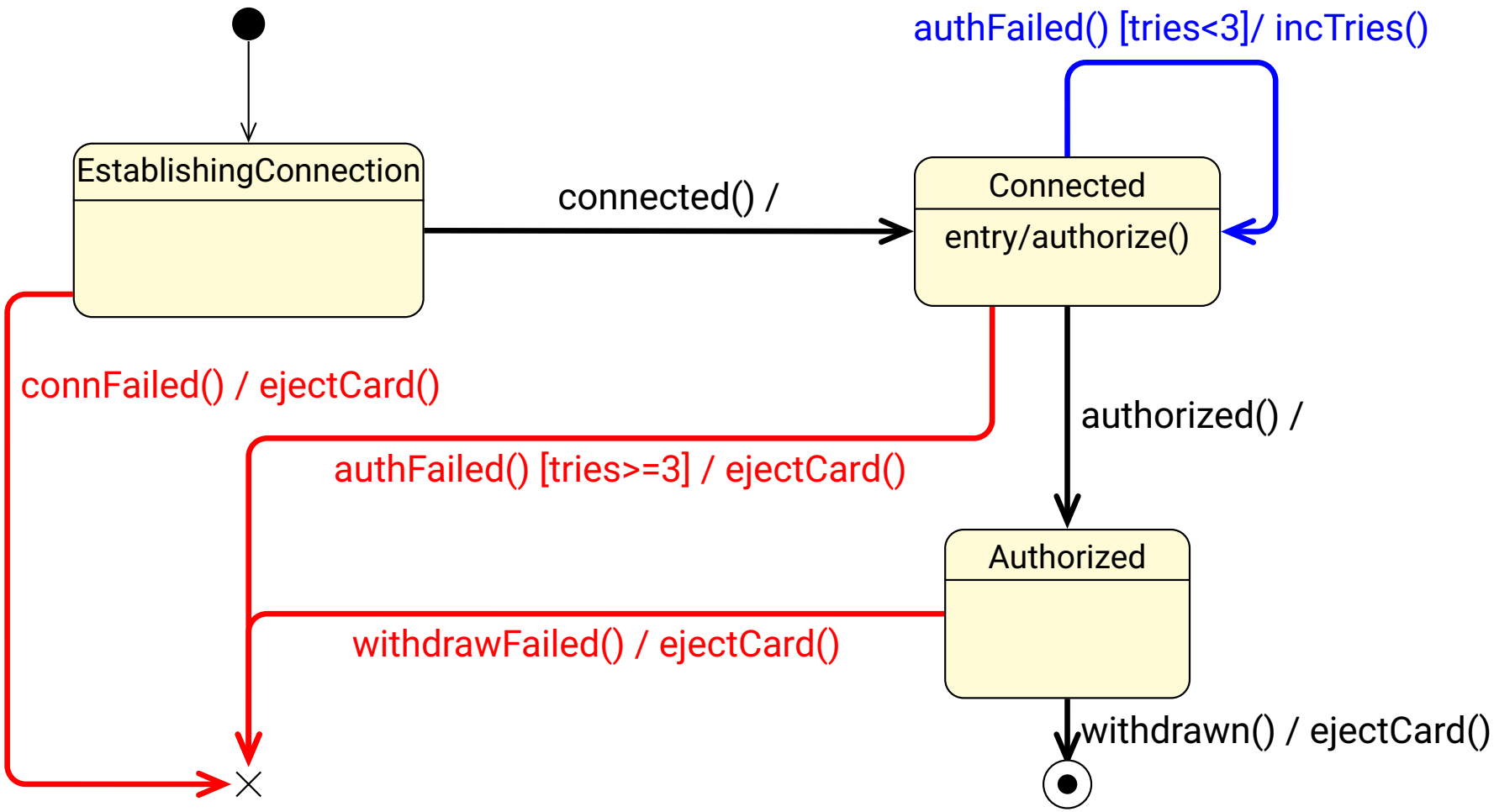


Transition Labels: *input?* (’[’ *guard* ’]’)*?* ’/’ *output?*

- All parts are optional (indicated by ?)
- Input (trigger) events are observations such as:
  - call event (start of operation)
  - time event (for example, time spent in a state)
  - change event (value of an attribute has changed)
- Guard is a Boolean expression
- Output (action) is an operation or domain-specific action expression

State Machine Diagram: Example

Credit Card Payment with PIN



State Machine Diagrams in Domain Modelling

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During domain modelling: State machine diagrams do not relate to code

Uses of State Machine Diagrams in Domain Modeling

Capture the action sequence of a use case

- Can combine several, related use cases
- Clarify the states an object can be in
- Help to clarify protocols
- Help to validate the domain model
- Help to complete the domain model (with properties / actions)

State machine diagrams should only be used to model non-trivial behavior

Literature

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