Requirement Engineering

Lecture 8: Requirements Documentation

Model-based Requirements Documentation

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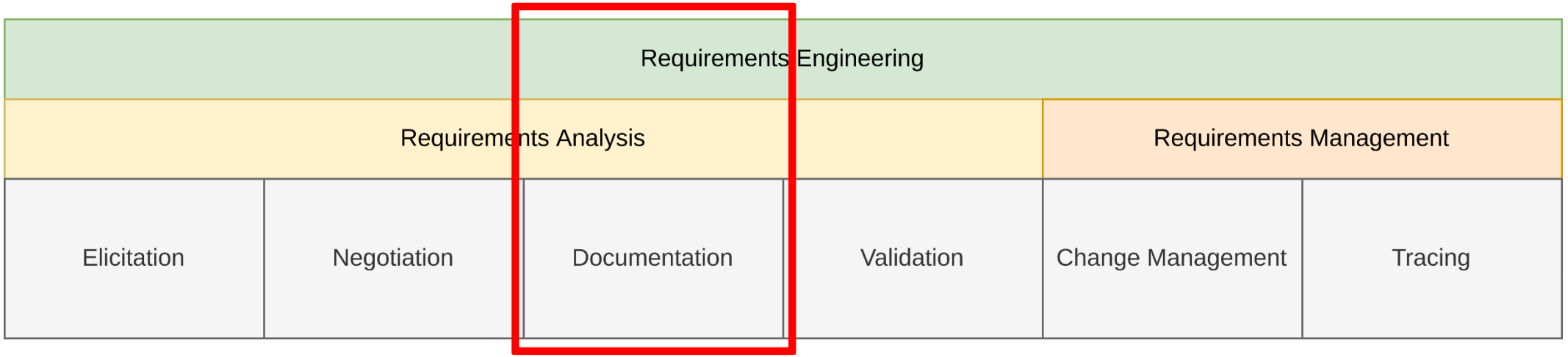
General Requirements Engineering Process

Overview



MODEL-BASED REQUIREMENTS DOCUMENTATION TECHNIQUES

Lecture 8: Requirements Documentation

Content

1. Model-based Requirements Documentation Techniques
    1. **Models in General**
    2. Goal Models
    3. Use Cases
    4. Data | Functional | Behavioral Perspective
    5. Agent-oriented Modelling

Model-based Requirements Documentation Techniques

Models in General – Requirements Model vs. Design Model

- Models are frequently used for system design
  - “Design Models”
  - E.g., architectural models

- Considerable difference between requirements models and design models
  - Requirements models depict aspects of the underlying problem
  - Design models document solutions chosen during system development

Model-based Requirements Documentation Techniques

Models in General – The Term “Model”

- According to Merriam-Webster:
  - *Structural design*
  - *A usually miniature representation of something*
  - *A system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs*

- We use the following definition in this lecture:
  - *A model is an abstract representation of an existing reality or a reality to be created.*

Model-based Requirements Documentation Techniques

Models in General – Properties of Models

- Mapping of reality
  - Aspects of the observed reality are mapped onto model elements
  - Descriptive model creation → Model documents the existing reality
  - Prescriptive model creation → Model prototypes fictious reality
  - Models can be both descriptive and prescriptive at the same time
    - Describes a stakeholder
    - Prescribes a use case of a system

Model-based Requirements Documentation Techniques

Models in General – Properties of Models

- Reduction of Reality
  - Models do not capture the complete reality
  - Instead, the models reduce the captured reality
  - Only particular aspects of the system are modeled
  - Subject matter is summarized during compression
- Pragmatic Property
  - Models serve a special purpose
  - Models are within a special context
    - **NOT general purpose!**
  - Purpose affects the construction of models and the reduction of the reality
  - Ideally contains only information pertaining to its purpose

Model-based Requirements Documentation Techniques

Models in General – Properties of Models

- Defined through **syntax** and **semantics**

- Syntax
  - Defines the modeling elements to be used
  - Specifies their valid combinations
- Semantics
  - Defines the meaning of the individual model elements
  - Foundation for the interpretation of the models

- Can be **formal**, **informal**, and **semiformal**
  - Depends on the magnitude of formal definitions

Model-based Requirements Documentation Techniques

Models in General – Advantages of Models

- Humans handle graphically depicted information better
  - Perceived faster
  - Memorized faster
  - Also true for requirements models

- Strictly defined focus
  - Everything not part of the focus of the model is removed → Removal of noise

- Harmonized level of abstraction
  - Modeling elements dictate the level of abstraction

Model-based Requirements Documentation Techniques

Models in General – Suppression of Details

- Complexity is reduced by abstraction
- Three main mechanisms
  - Selection
    - Selects a particular aspect to be depicted by the model
    - Other aspects are ignored completely, i.e., not part of the model
  - Aggregation
    - Combines aspects into aggregated aspects
    - Condenses information
  - Classification/generalization
    - Identifies common features
    - Suppresses differences between the common features
    - Commonalities are represented as generalized information

Model-based Requirements Documentation Techniques

Models in General – UML

- Object Management Group (OMG) standard
  - Current version UML 2.5.1
- Graphical notation for the analysis, design, and documentation of object-oriented systems
- UML is **not**
  - a development process
  - specialized for a certain topic
  - complete & formal
    - Cannot be complied without additional information
    - → Semiformal
  - Capable of semantics
    - UML only provides a syntax
    - Semantics depend on the reader of the document

Model-based Requirements Documentation Techniques

Goal Models – Goals in General

- Goals are the stakeholders description of system properties
  - What they want from the system
- Effort for goal considerations usually minimal
- Positive impact of goal modeling is high
  - Especially concerning the comprehensiveness and quality

Lecture 8: Requirements Documentation

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Model-based Requirements Documentation Techniques

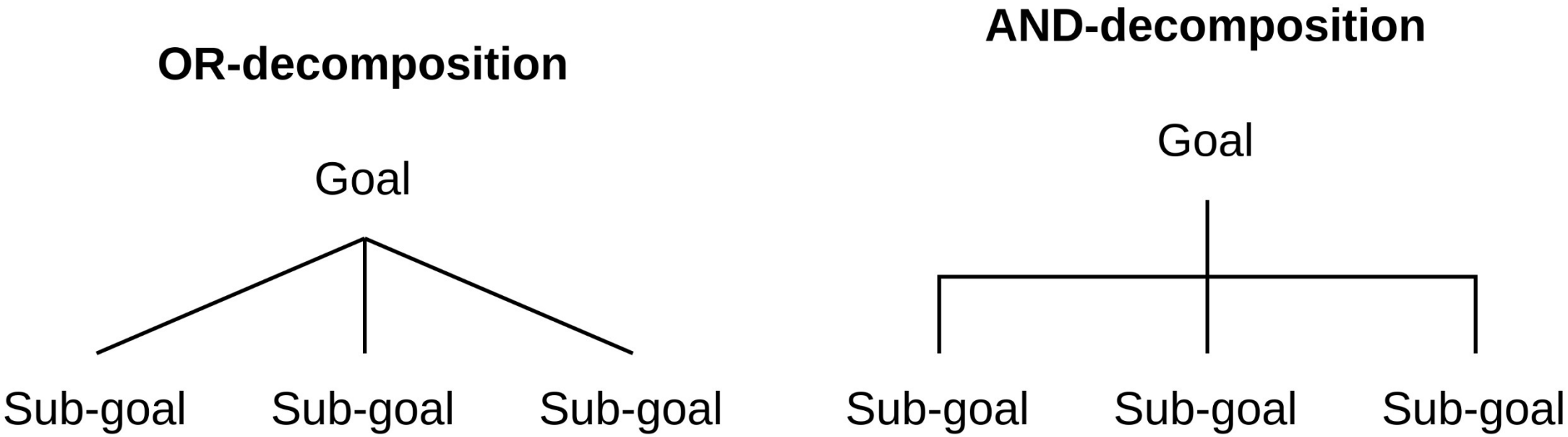
Goal Models – AND / OR Trees

- Documents hierarchical decompositions of goals into sub-goals

- Two types of decompositions
  - AND → All sub-goals must be fulfilled
  - OR → At least one sub-goal must be fulfilled

Model-based Requirements Documentation Techniques

Goal Models – AND / OR Trees



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Model-based Requirements Documentation Techniques

Use Cases – Overview

- Method to document functionalities
  - Planned
  - Of existing system
- Relatively simple models
- Two concepts
  - Use case diagrams
  - Use case specification
- Both should be used in conjunction

Model-based Requirements Documentation Techniques

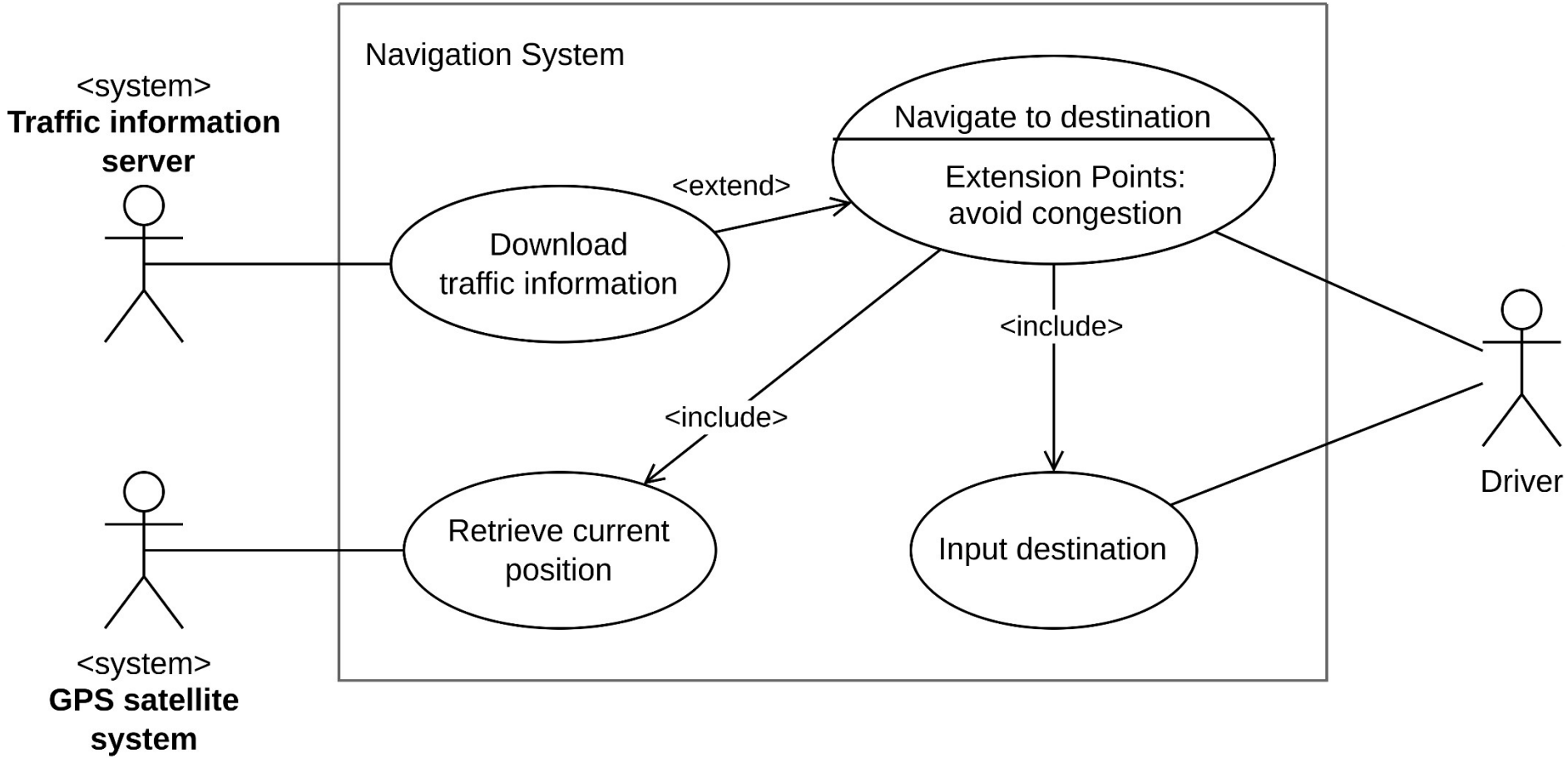
Use Cases – UML Use Case Diagrams

- Models to schematically depict:
  - Functions from a user's point of view
  - Interrelations of functions of a system
  - Relations between functions and their environment

- **We do not cover all concepts of use case diagrams in this lecture**
  - Additional information can be found in the literature

Model-based Requirements Documentation Techniques

Use Cases – UML Use Case Diagram (Example)



Based on K. Pohl, C. Rupp (2011) – Requirements Engineering Fundamentals: A study guide for Requirements Engineering Foundation Level

Model-based Requirements Documentation Techniques

Use Cases – Issues of UML Use Case Diagrams

- Diagrams do not contain details
  - Very high level
  - Very abstract

- Examples for open questions
  - How does the driver communicate with the Navigate to destination use case?
  - Is there an order in the inclusion of the use cases Retrieve current location and Input destination?

Model-based Requirements Documentation Techniques

Use Cases – Use Case Specifications

- Use case specifications provide details to the diagrams
- Specifications documented textually
- Not simple prose, but in form of templates (usually tabular)
- The template defines the concrete information contained in the use case specification

Model-based Requirements Documentation Techniques

Use Cases – Use Case Specification Template

- Template prescribes the following information
  - Attributes for unique identification of use cases
  - Management attributes
  - Attributes for the description of the use case
  - Specific use case attributes, e.g.,
    - the trigger event,
    - actors,
    - pre- and post-conditions,
    - the result of the use case,
    - the main scenario,
    - alternative and exception scenarios,
    - cross references,
    - quality requirements

Model-based Requirements Documentation Techniques

Use Cases – Use Case Specification Template (Example)

Section	Content
Designation	UC-12-37
Name	Navigate to destination
Authors	John Smith, Sandra Miller
Priority	Importance for system success : high Technological risk : high
Criticality	High
Source	C. Warner (domain expert for navigation systems
Person Responsible	J. Smith
Description	The driver of the vehicle types the name of the destination. The navigation system guides the drive to the desired destination.
Trigger event	The driver wishes to navigate to his destination
Actors	Driver, traffic information system, GPS satellite system

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Model-based Requirements Documentation Techniques

Use Cases – Use Case Specification Template (Example)

Section	Content
Pre-conditions	The navigation system is activated
Post-conditions	The driver has reached his destination
Result	Route guidance
Main scenario	1. The navigation system asks for the desired destination 2. The driver enters the desired destination 3. The navigation system pinpoints the destination in its maps 4. On the basis of the current position and the desired destination, the navigation system calculates a suitable route 5. The navigation system compiles a list of waypoints 6. The navigation system shows a map of the current position and shows the route to the next waypoint 7. When the last waypoint is reached, the navigation system shows “destination reached” on the screen

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Model-based Requirements Documentation Techniques

Use Cases – Use Case Specification Template (Example)

Section	Content
Alternative scenario	4a. Calculation of the route must honor traffic information and avoid traffic congestions. 4a1. The navigation system queries the server for updated traffic information. 4a2. The navigation system calculates a route that does not contain any traffic congestions.
Exception scenarios	Trigger event: The navigation system does not receive GPS signal from the GPS satellite system.
Qualities	→ QR.04 (reaction time upon user input) → QR.15 (operating comfort)

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Model-based Requirements Documentation Techniques

Modelling Requirements in the Three Perspectives

- Different perspective → Different models

- **Data perspective**
  - Entity-relationship diagrams
  - UML class diagrams
- **Functional perspective**
  - Data flow diagrams
  - UML activity diagrams
- **Behavioral perspective**
  - Statecharts
  - UML state machine diagrams

Model-based Requirements Documentation Techniques

Data Perspective – Entity-relationship Diagrams

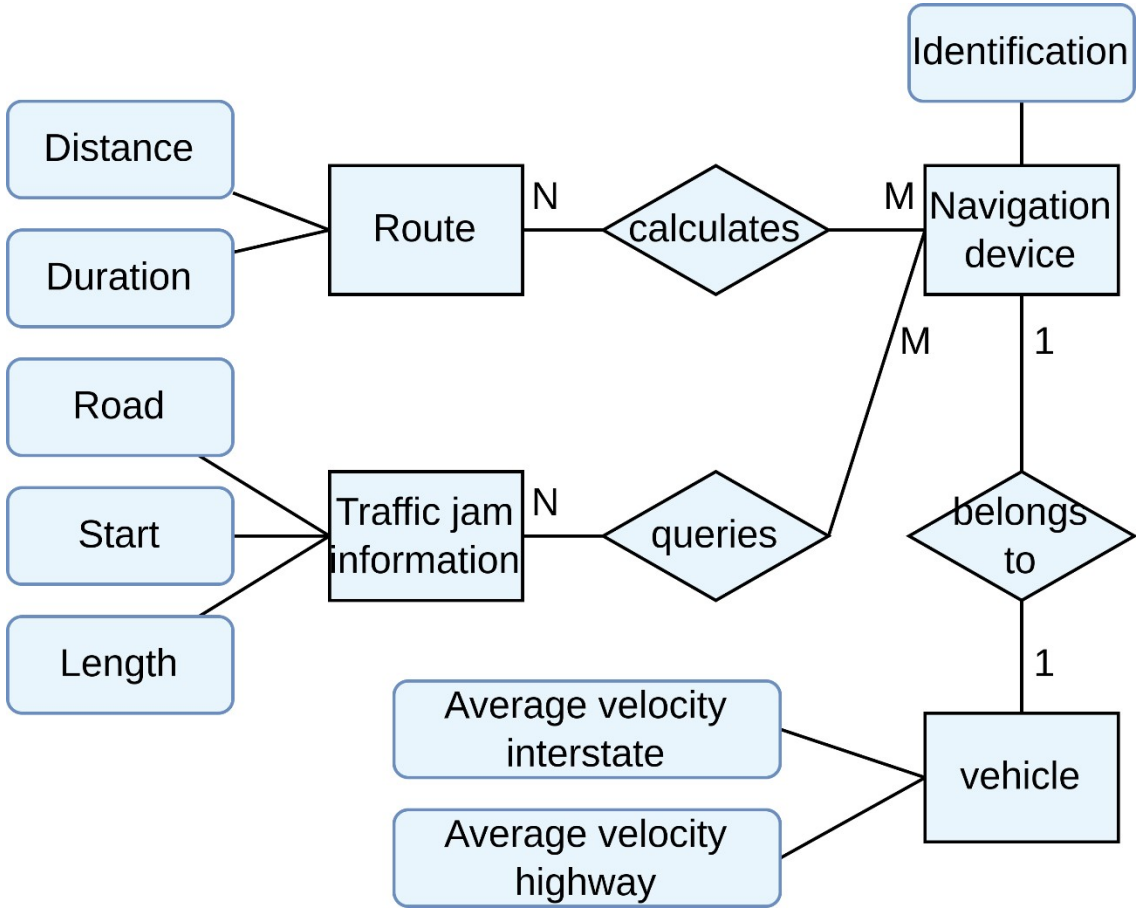
- Concept from the world of databases
- Used to model data (entities) and their relationships

- Extensions of entity-relationship diagrams developed over the years
  - Min/max notations for cardinalities
  - Inheritance mechanism
  - ...

- (Extensions out of scope in this lecture)

Model-based Requirements Documentation Techniques

Data Perspective – Entity-relationship Diagrams (Example)



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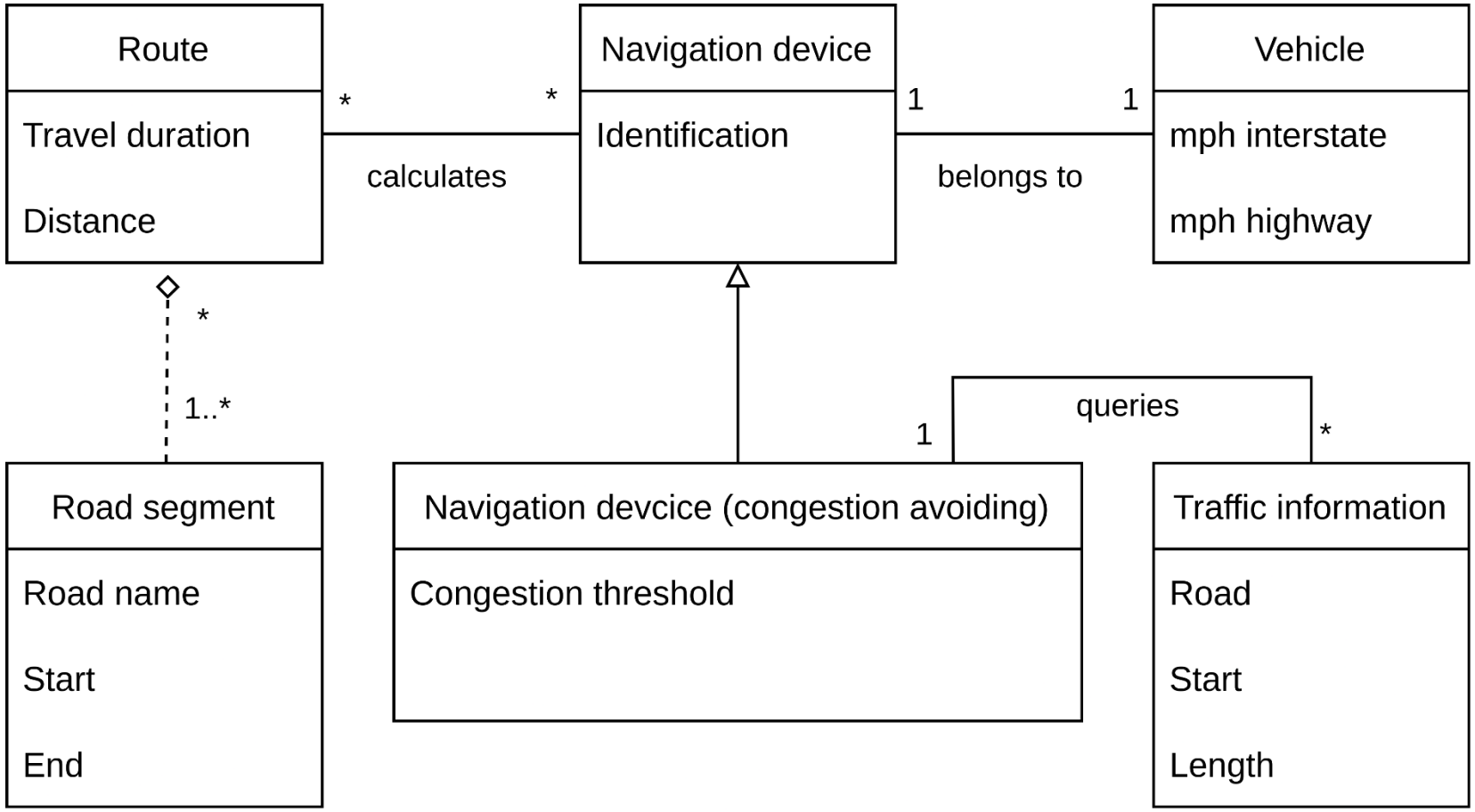
Model-based Requirements Documentation Techniques

Data Perspective – UML Class Diagrams

- Consists of classes and their associations
- In principle, similar to entity-relationship diagrams
  - Classes ~ entity types
  - Associations ~ relation types
- Class diagrams more powerful than entity-relationship diagrams

Model-based Requirements Documentation Techniques

Data Perspective – UML Class Diagrams (Example)



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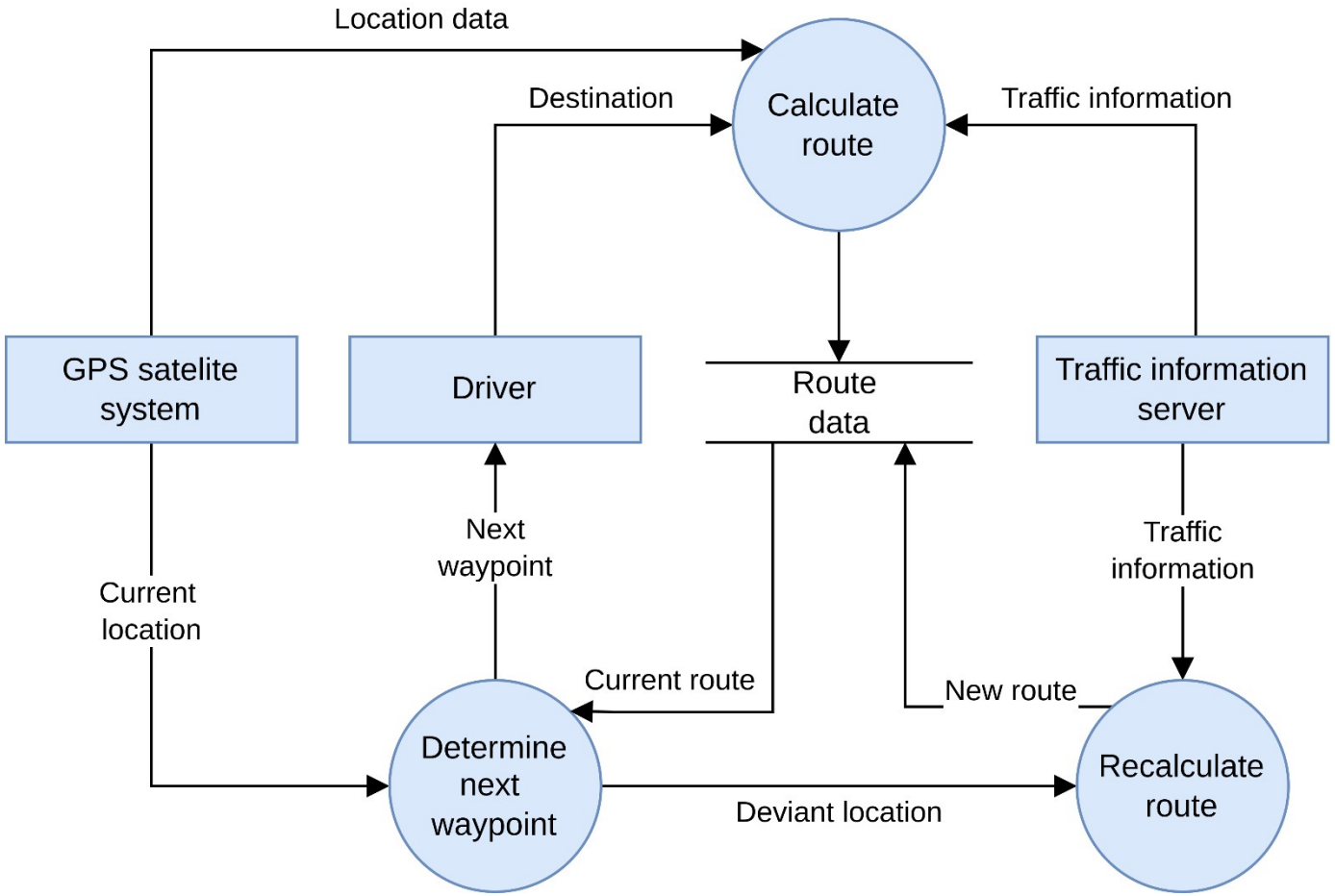
Model-based Requirements Documentation Techniques

Functional Perspective – Data Flow Diagrams

- Model the flow of the data through the system
  - Input/Output data
  - Recipients of the data
- Can be applied on different levels of abstraction
  - Requirements on different levels of abstraction possible

Model-based Requirements Documentation Techniques

Functional Perspective – Data Flow Diagrams (Example)



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Functional Perspective – UML Activity Diagrams

- Method to model action sequences
- Depict the control flow between activities and actions
- Can include the data flow (optional!)

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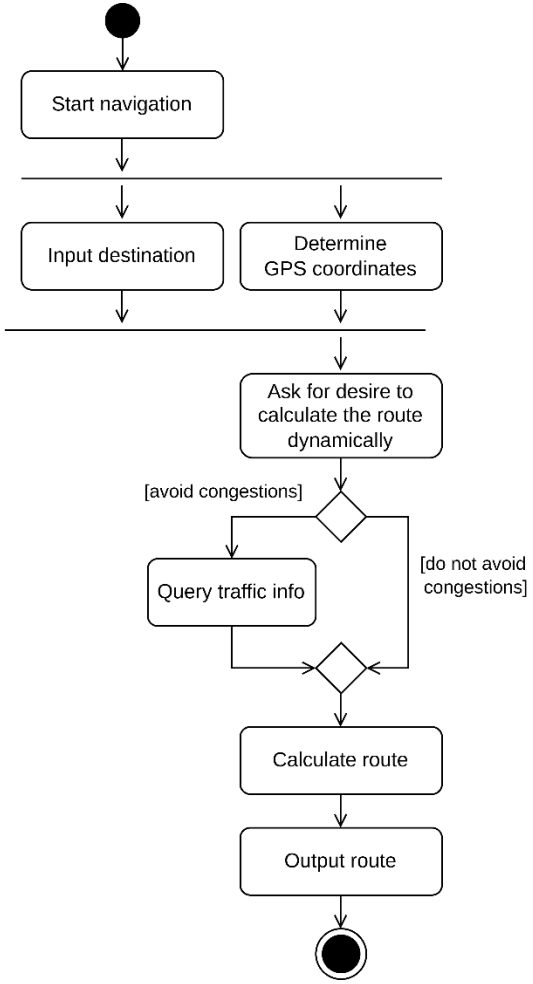
Functional Perspective – UML Activity Diagrams (Example)



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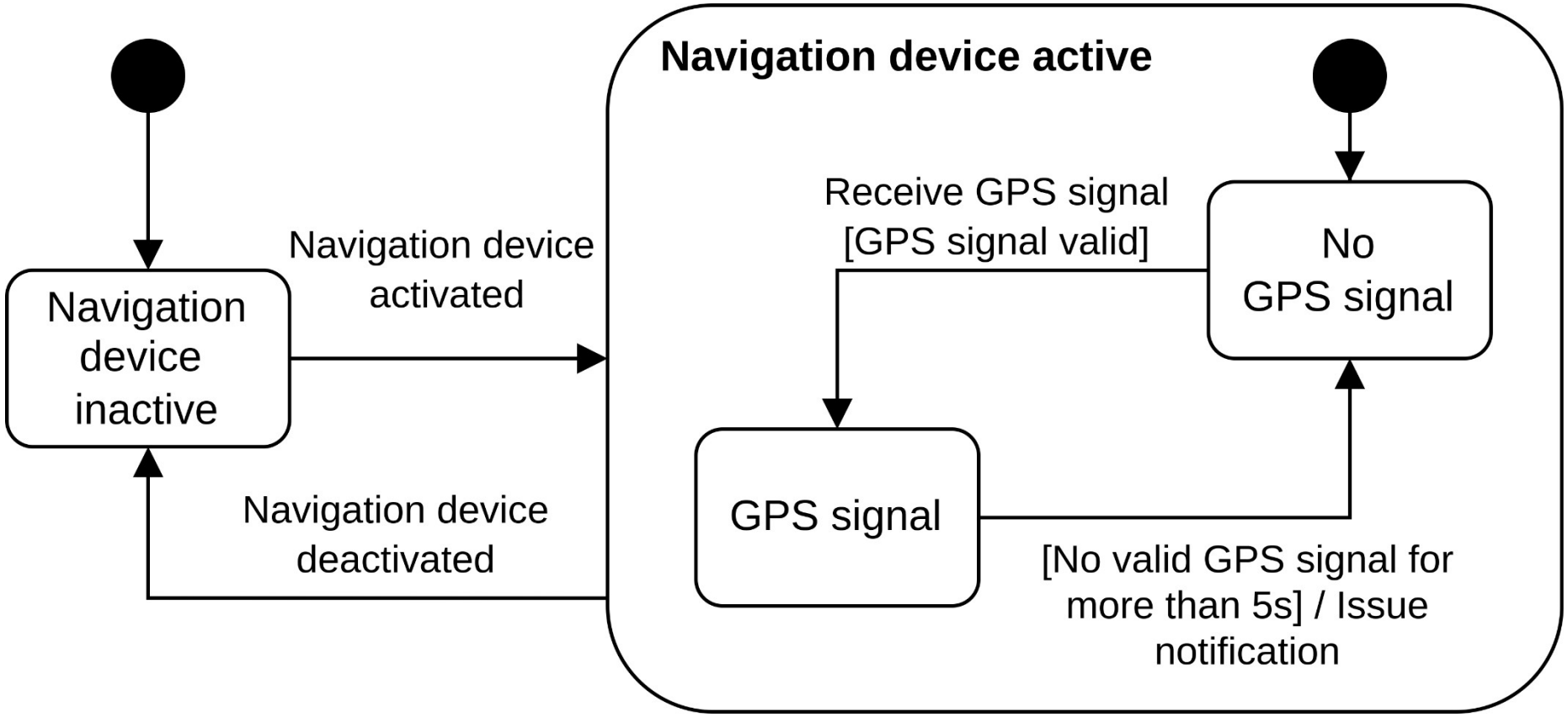
Model-based Requirements Documentation Techniques

Behavioural Perspective – Statecharts

- Extension of finite automata
- Support hierarchization of states
- Allow concurrent behavior

Model-based Requirements Documentation Techniques

Behavioural Perspective – Statechart (Example)



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    5. **Agent-oriented Modelling**

Agent-oriented Modelling

Concepts and Definitions

- Goal: A situation description that refers to the intended state of the environment. Goals can:
  - be *functional* or *non-functional (quality).*
  - have sub-goals.
- “Goals are expressed by using nouns, verbs, and (optionally) adjectives. The nouns tend to be more of a state, and the verbs more into the activities that are needed to achieve a goal.”
- e.g., if a *message* needs to be *transmitted securely*, the functional goal ‘*Transmit Message*’ can be associated with the quality goal ‘*Securely*’

L. Sterling, K. Taveter (2009) – The Art of Agent-Oriented Modeling

Agent-oriented Modelling

Motivation: Why AOM?

- Most (if not all) processes in software systems are elicited by *Agents* playing a certain *Role* in the system, to achieve some *Goal.*
- AOM is a tool for *“modelling systems with multiple agents, both human and manmade, interacting with a diverse collection of hardware and software in a complex environment”*
- AOM models are clear and easily understandable for stakeholders → useful for Requirements Engineering

L. Sterling, K. Taveter (2009) – The Art of Agent-Oriented Modeling

Agent-oriented Modelling

Goal vs. Requirement

Goal	Requirement
Single desired result	Statement of need
One goal may consist of several requirements	One requirement may be related to many goals

- No one to one mapping between goals and requirements is possible

Agent-oriented Modelling

Concepts and Definitions

- How does one identify functional and non-functional goals?
  - Functional goals usually describe **what** a system must accomplish = Identification depends heavily on the system.
  - Non-functional goals describe **how** the system must accomplish those goals, in terms of standards and quality = Identification can depend on functional goals.
  - **However**, there are many commonalities: Reliability, Availability, Security, …..

https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781119202660.app6

Agent-oriented Modelling

Concepts and Definitions

- Role: Some capacity or position that fascilitates the system to achieve it's goals. Roles express functions, expectations, and obligations of the agents enacting them.
  - eg. Network Administrator, Firewall
- Agent: An entity that can act in the environment, perceive events, and reason.
  - Can be human or software

L. Sterling, K. Taveter (2009) – The Art of Agent-Oriented Modeling

Agent-oriented Modelling

Concepts and Definitions

- Activity: Some action performed by an agent playing a role in pursuance of a system goal.
- Environment: An abstraction that provides the surrounding conditions for agents to exist and that mediates both the interaction among agents and the access to resources.

L. Sterling, K. Taveter (2009) – The Art of Agent-Oriented Modeling

Agent-oriented Modelling

Models

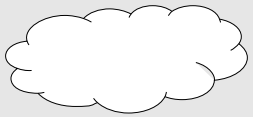
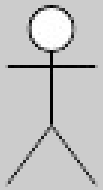
Models that we will take a look at:

- Goal Models
- Behavioural Interface Models

Agent-oriented Modelling

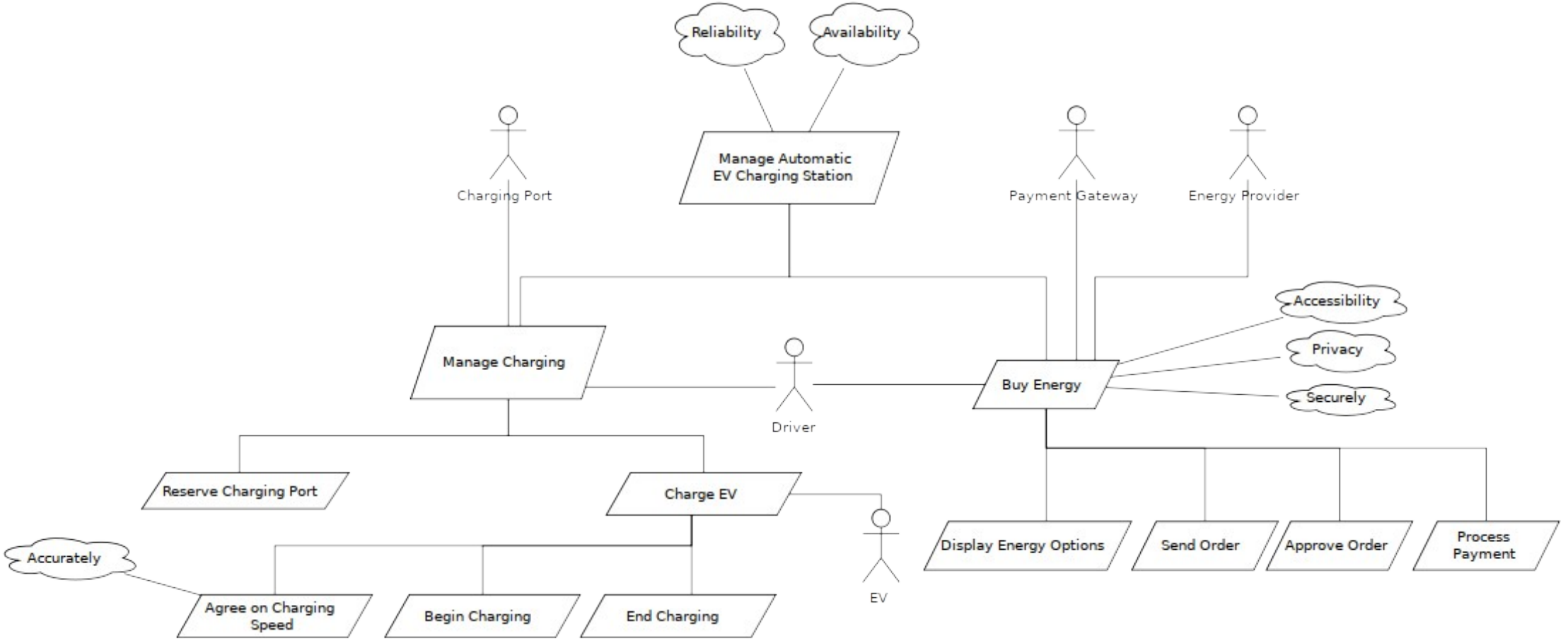
Goal Models

- Goal models hierarchically express the relationships between goals (functional and non-functional) and the roles played by various agents in pursuit of those goals.
- Sterling and Taveter's AOM Goal models omit AND/OR decomposition for simplicity.

Symbol	Meaning
	Goal
	Quality Goal
	Role
	Reltionship between goals
	Relationship between goals and quality goals

Agent-oriented Modelling

Goal Model Example: Automated EV Charging Station



Agent-oriented Modelling

Behavioural Interface Models (BIM)

- Behavioral Interface Models model the behaviour of agents playing their roles
  - Models *Behavioural Units (= Activities)*
  - Represented as a table ↓

Activity	Trigger(s)	Precondition(s)	Postcondition(s)
Activity Name	*Event(s) that trigger(s) the activity*	*Conditions for Activity to proceed*	*Conditions for Activity to be considered complete*
…	…	…	…

Agent-oriented Modelling

BIM Example: Automated EV Charging Station (Manage Charging)

Activity	Trigger(s)	Precondition(s)	Postcondition(s)
Reserve Charging Port(CP)	Driver wants to charge EV	Driver has bought energy, CP is free, EV is ready to charge	Driver has reserved CP
Charge EV	〃	Driver has reserved CP	Driver has charged EV
Agree on charging speed	〃	Driver has reserved CP, Max CP speed ≥ Min EV speed, Max EV speed ≥ Min CP speed	Charging speed is agreed upon
Begin Charging	〃	Charging speed is agreed upon	EV has begun charging
End Charging	None	EV has competed charging	Driver has charged EV, CP is free

SUMMARY

Summary

- Conceptual models as a means for requirements documentation
  - Abstraction and good overview vs. learning a modeling language
  - Different models for different purposes → Model needs to fit the purpose
- UML provides models for almost anything
  - We only covered a small part → Other UML models can also be useful for requirements documentation
  - UML is not the only answer → Other models work fine, too.

Questions?