Freie Universität Berlin

Course "Softwaretechnik"
Analysis: Dynamic Modeling

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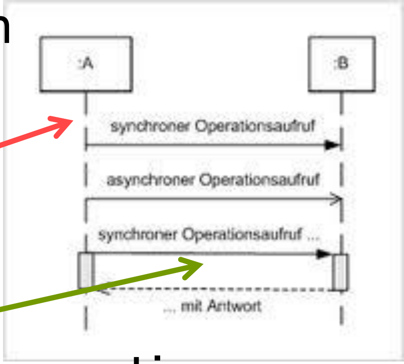
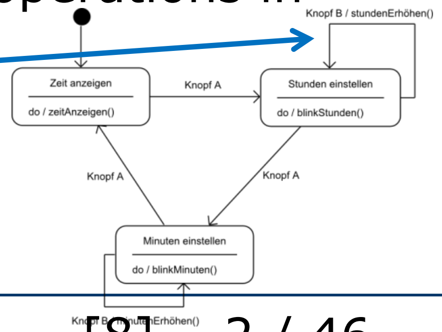
- Dynamic modeling
  - Sequence diagrams
  - State diagrams
- Using dynamic modeling for the design of user interfaces
- Requirements analysis document template
- Requirements analysis model validation

How do you find classes?

- In previous lectures we have already established the following sources
  - Application domain analysis: Talk to client to identify abstractions
  - Application of general world knowledge and intuition
  - Scenarios
  - Use Cases
  - Textual analysis of problem statement (Abbott)

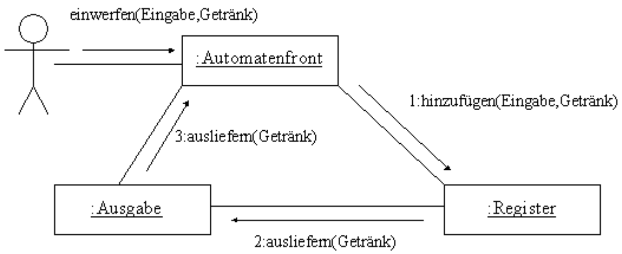


- Today we show how to identify classes and their operations and attributes from dynamic models
  - Activity lines in sequence diagrams identify candidates for classes
  - Messages in sequence diagrams may turn up as operations in classes
  - Actions and activities in statecharts or activity diagrams are candidates for public operations in classes

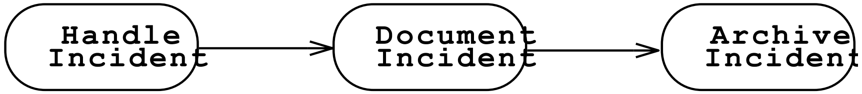


Dynamic Modeling with UML

- Diagrams for dynamic modeling
  - Interaction diagrams describe dynamic behavior between objects
    - Example behavior only, not general specifications
  - Statecharts describe the dynamic behavior of a single object
- Interaction diagrams
  - Sequence diagram:
    - Dynamic behavior of a set of objects arranged in time sequence
    - Good for real-time specifications and complex scenarios
  - Collaboration diagram:
    - Different but roughly equivalent diagram type (not used a lot)



- Statechart diagram:
  - A state machine that describes the response of an object of a given class to the receipt of outside stimuli (Events)
  - Activity Diagram: A special type of statechart diagram, where all states are action states



Dynamic Modeling

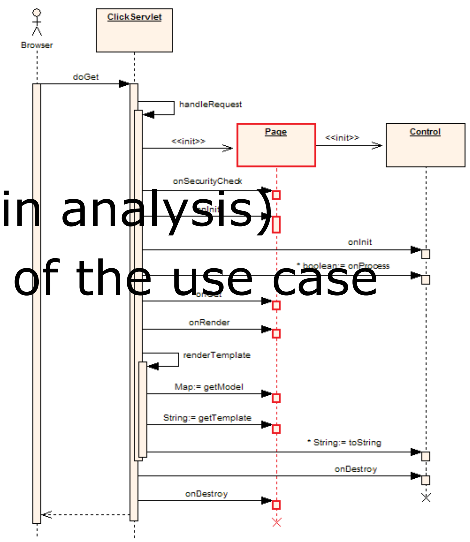
- Definition of dynamic model:
  - A collection of multiple behavior diagrams (such as statechart, activity, and sequence diagrams),
    - usually at least one regarding each important class

    with important dynamic behavior

- Purpose:
  - Understand behavioral requirements
  - Detect and supply methods for the object model

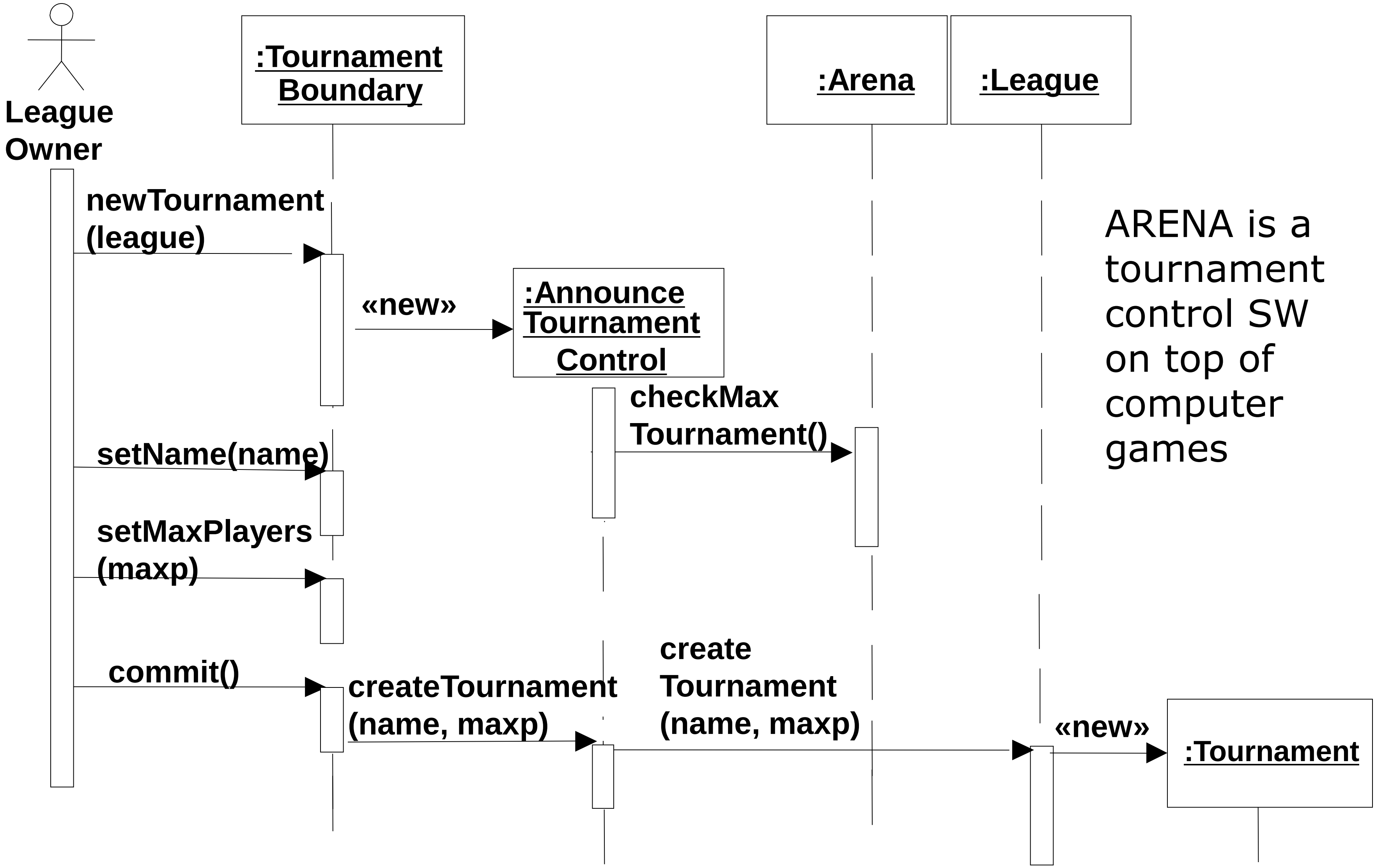
- How do we do this?
  - Start with use case or scenario, plus identification of classes
  - Model interaction between objects ➔ sequence diagram
  - Model dynamic behavior of a single object ➔ statechart diagram

Heuristics for sequence diagrams



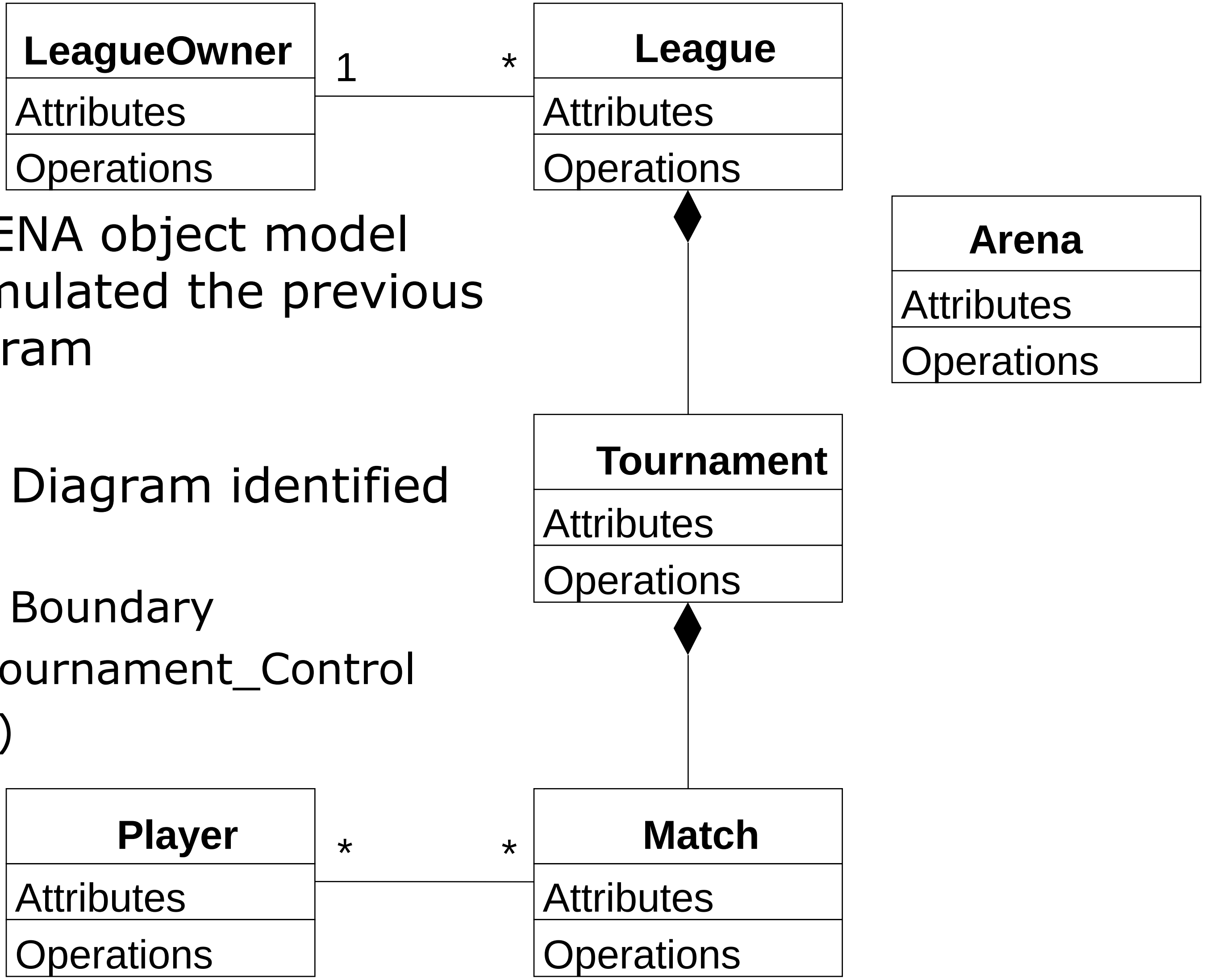
- A typical layout:
  - 1st column: The *actor* who initiated the use case
  - 2nd column: A *boundary object* (perhaps missing in analysis)
  - 3rd column: The *control object* managing the rest of the use case
  - further columns: the other participating objects
- Creation:
  - Control objects are often created at the initiation of a use case
  - Additional boundary objects are often created by control objects
- Access:
  - Entity objects are accessed by control and boundary objects
  - Entity objects should never call boundary or control objects:
    - This makes it easier to share entity objects across use cases and
    - makes entity objects resilient against technology-induced changes in boundary objects

An ARENA sequence diagram: create tournament



ARENA is a tournament control SW on top of computer games

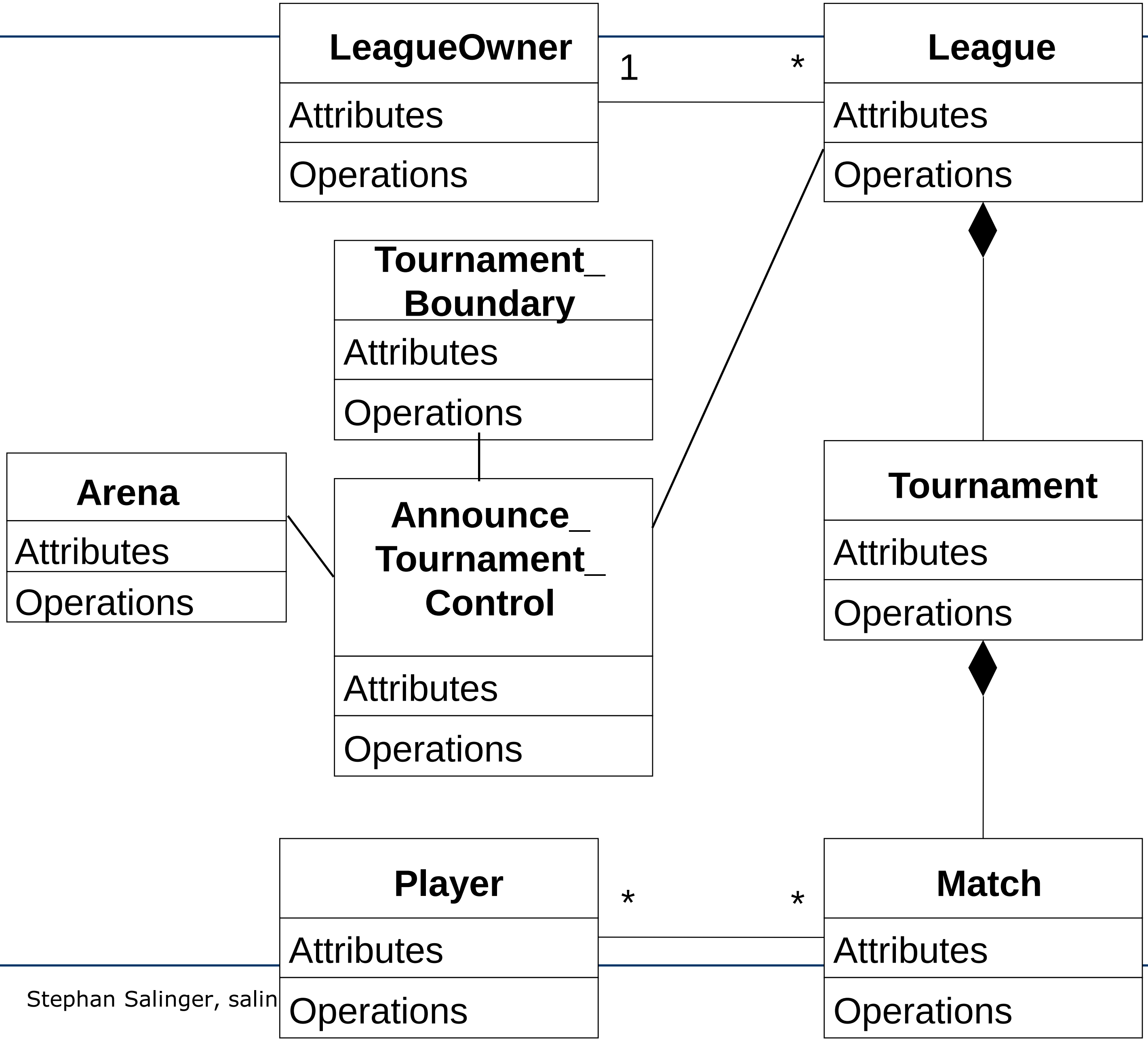
ARENA's Object Model (before)



- This is the ARENA object model before we formulated the previous sequence diagram
- The Sequence Diagram identified new classes
  - Tournament Boundary
  - Announce_Tournament_Control

  (see next slide)

ARENA's Object Model (new)



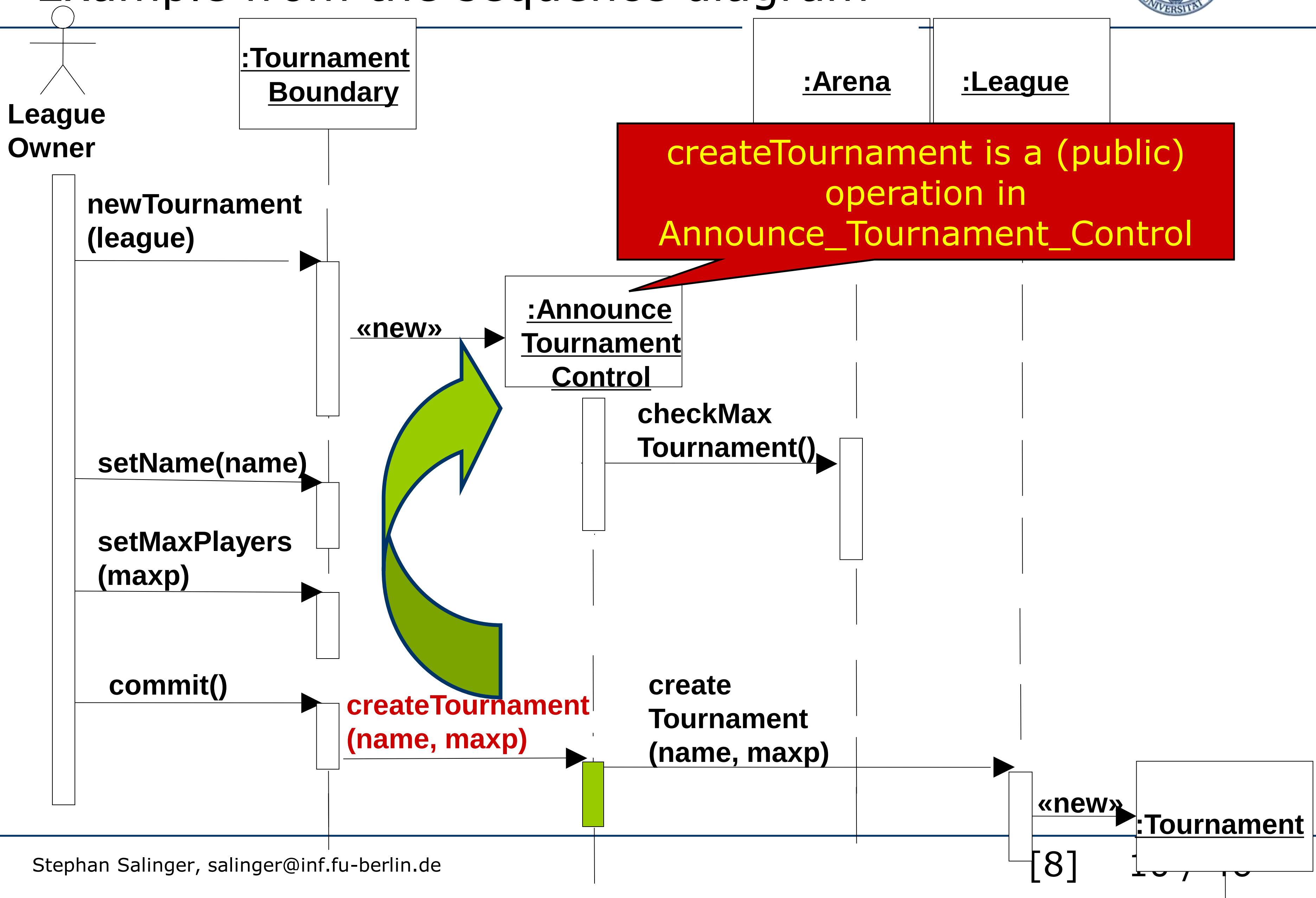
Impact on ARENA's Object Model (2)

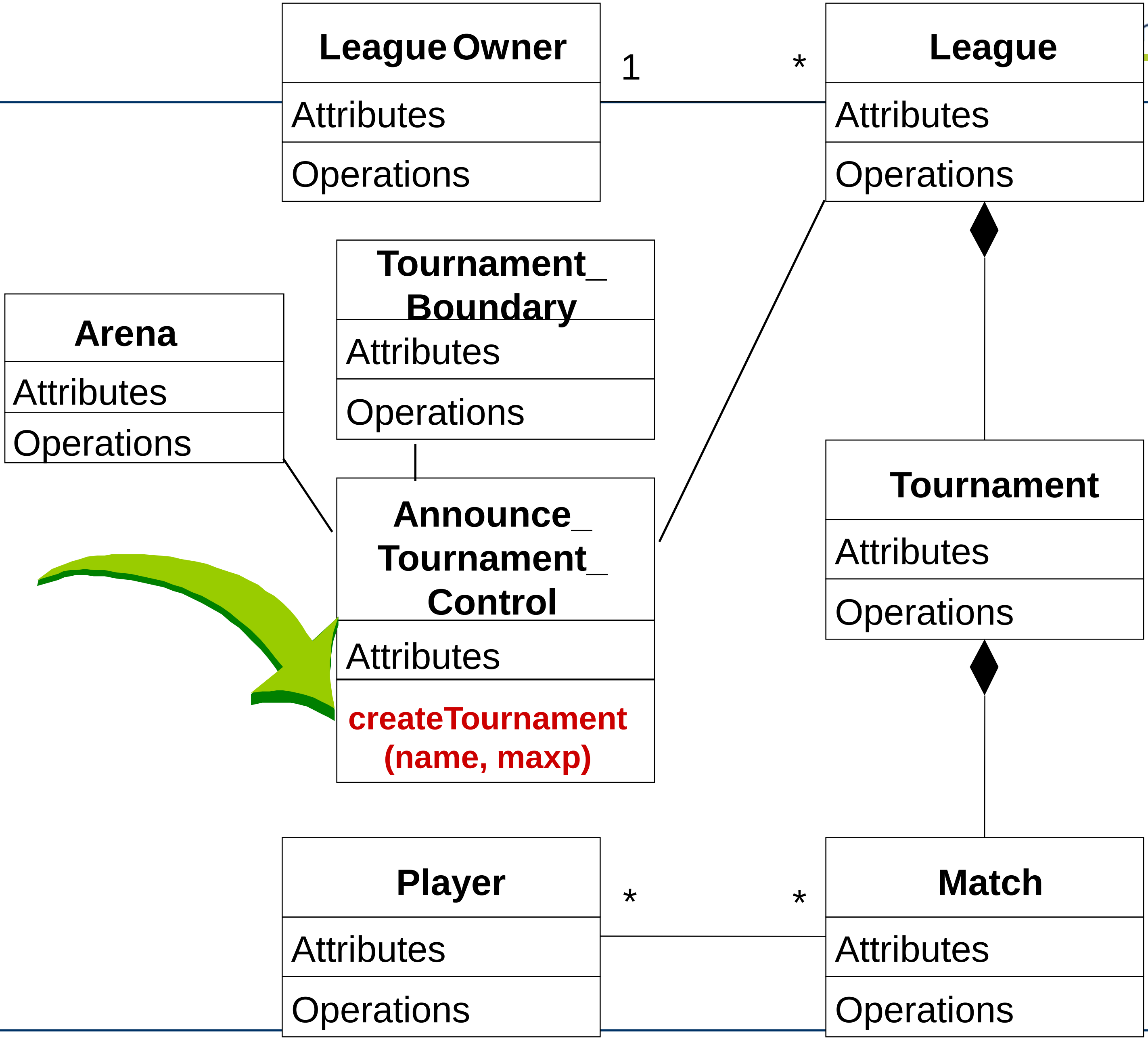
- The Sequence Diagram also supplied us several new events
  - newTournament(league)
  - setName(name)
  - setMaxPlayers(maxp)
  - commit()
  - checkMaxTournaments()
  - createTournament(name, maxp)

Who "owns" these events?

- For each object that receives an event
  there is a public operation in the associated class
  - The name of the operation is usually the name of the event

Example from the sequence diagram




League Owner
Attributes
Operations
1
*
League
Attributes
Operations
Tournament_ Boundary
Attributes
Operations
Arena
Attributes
Operations
Announce_ Tournament_ Control
Attributes
createTournament (name, maxp)
Tournament
Attributes
Operations
Player
Attributes
Operations
*
*
Match
Attributes
Operations

What else can we get out of sequence diagrams?

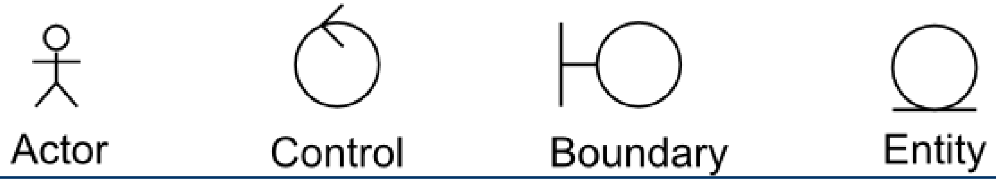
- Sequence diagrams are derived from use cases
  - We therefore see the structure of the use cases

- The structure of the sequence diagram helps us to determine how decentralized the system should be

- We distinguish two basic structures of sequence diagrams (Ivar Jacobson):
  - Fork-style diagrams (central control)
  - Stair-style diagrams (distributed control)

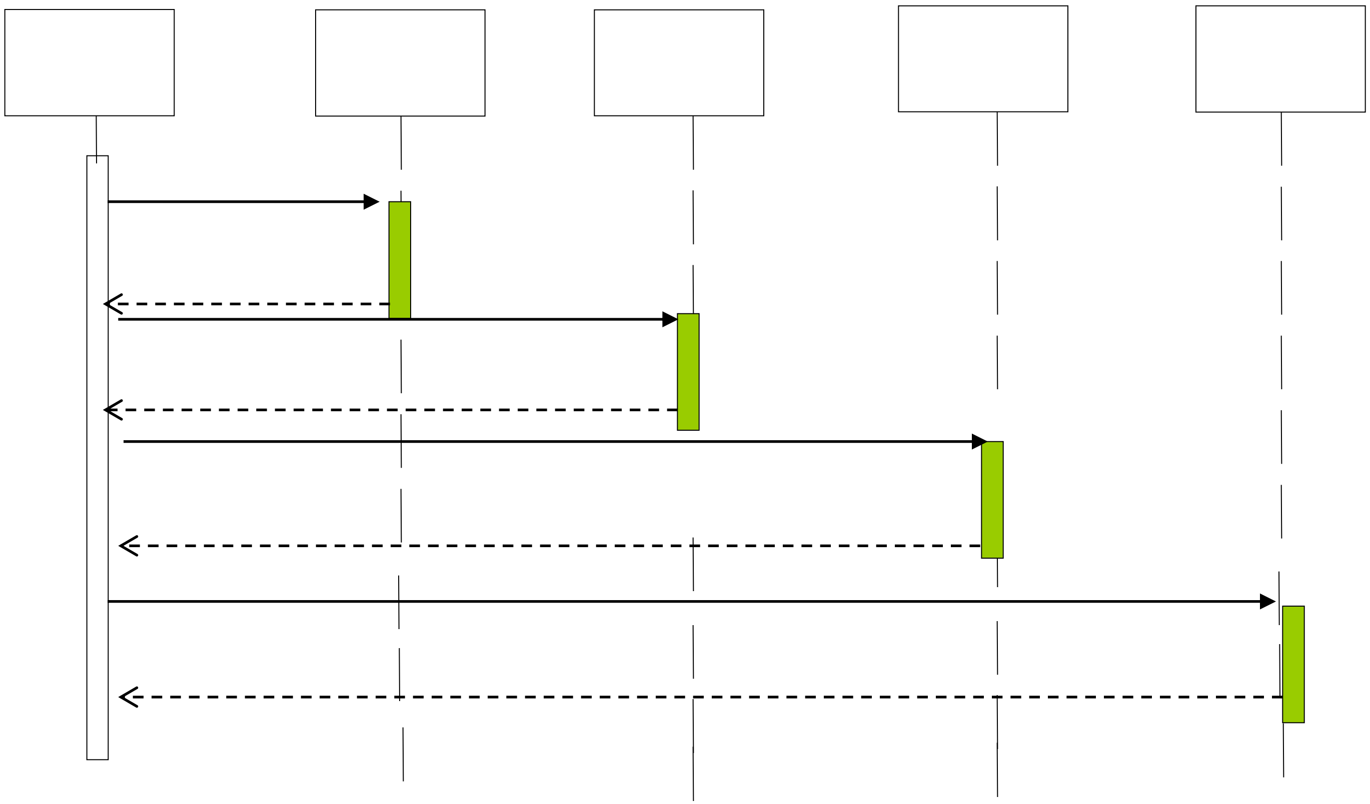
(see next slides)

btw:



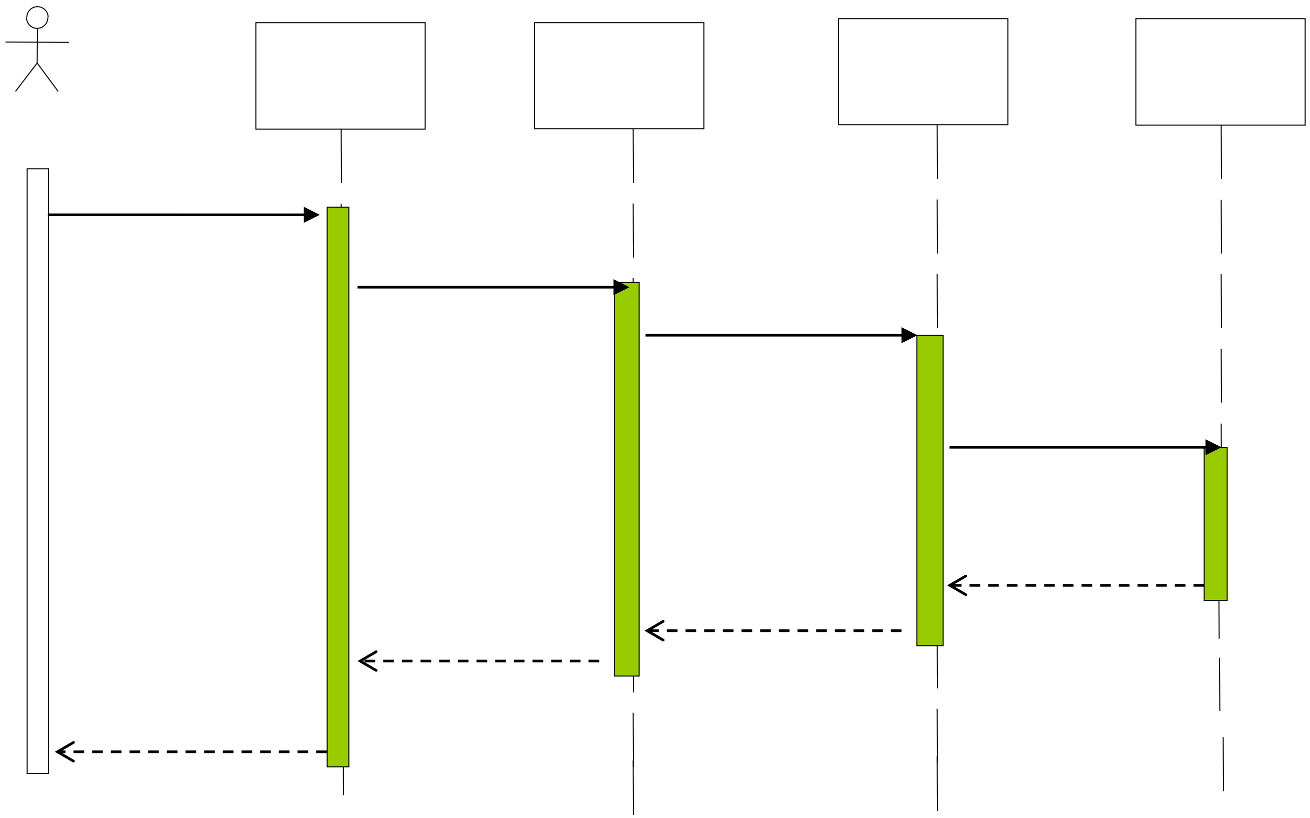
Central control: Fork diagram

- Much of the dynamic behavior is placed in a single object, usually the control object
  - It knows all the other objects and uses them for direct questions and commands



Decentralized control: Stair diagram

- The dynamic behavior is distributed.
  Each object delegates some responsibility to other objects
  - Each object knows only a few of the other objects and knows which objects can help with a specific behavior



Fork or Stair?

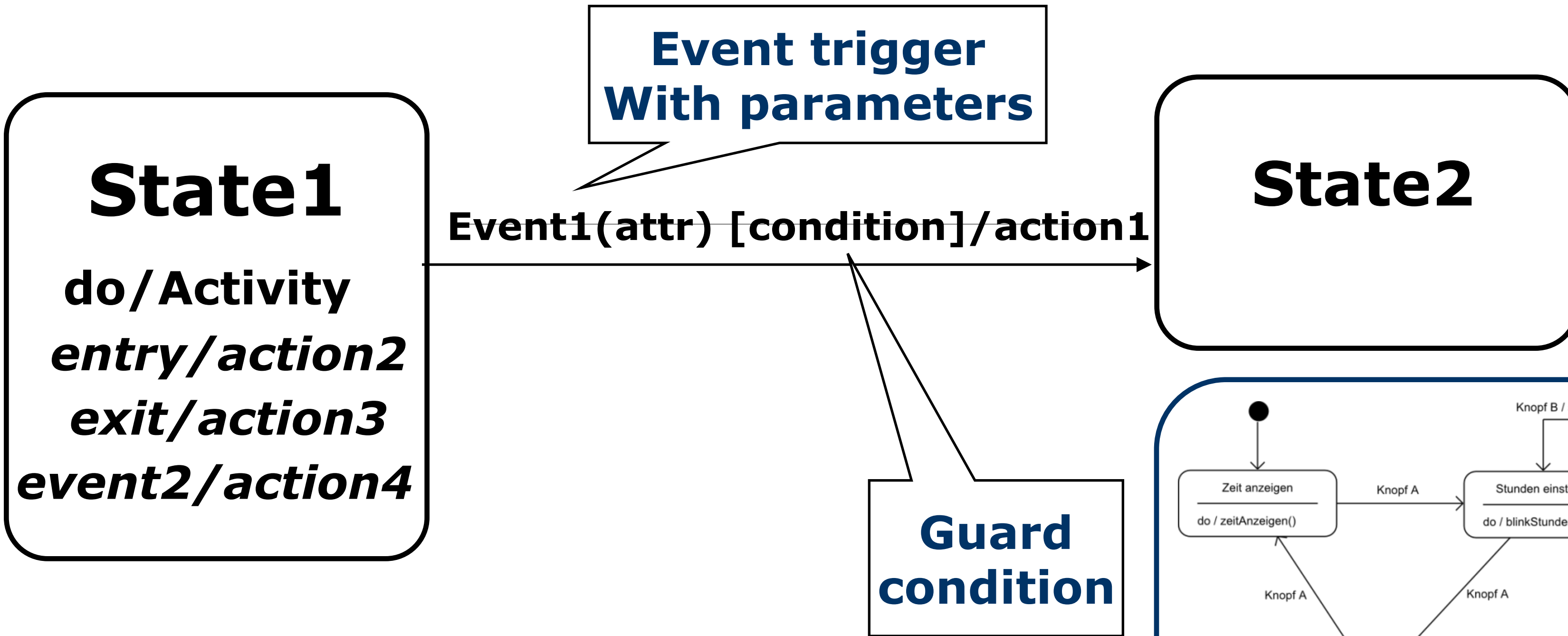
Which of these diagram types should be chosen?

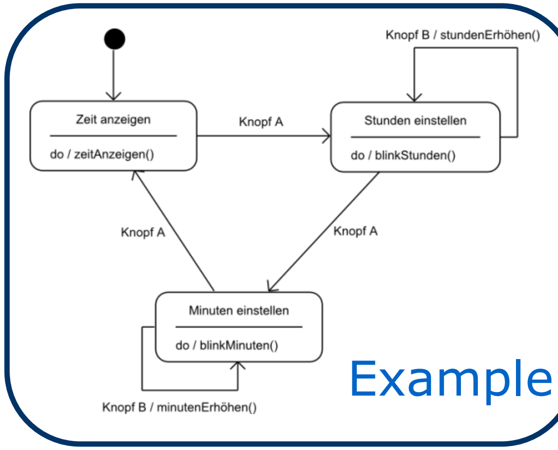
- Object-oriented fans claim the stair structure is better
  - "The more the responsibility is spread out, the better"
- However, this is not always true
  - One should usually have a "suitable" mix of both forms
  - (see also design patterns "Mediator", "Façade")

Better heuristics:

- Decentralized control structure
  - The operations have a strong connection
  - The operations will always be performed in the same order
- Centralized control structure (better support of change)
  - The operations can change order
  - New operations can be inserted as a result of new requirements

UML statechart diagram notation

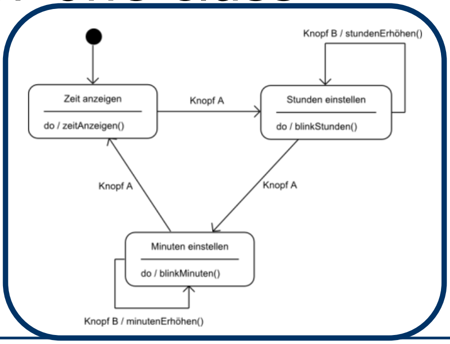




- Notation based on work by Harel
  - UML adds a few object-oriented modifications
- A UML statechart diagram can be mapped into a finite state machine

Statechart diagrams

- Graph whose nodes are states and whose directed arcs are transitions labeled by event names
- We distinguish between two types of elements in statecharts:
  - Activity: Operation that takes time to complete
    - associated with states
    - (in UML:) can be described by its own Activity diagram
  - Action: "Instantaneous" operation (in UML: elementary op.)
    - associated with events
    - associated with states (reduces drawing complexity): Entry, Exit, Internal Action
    - (May in fact have structure, too, but the present statechart ignores it)
- A statechart diagram relates events and states for one class
  - An object model with a set of objects can have a corresponding set of state diagrams



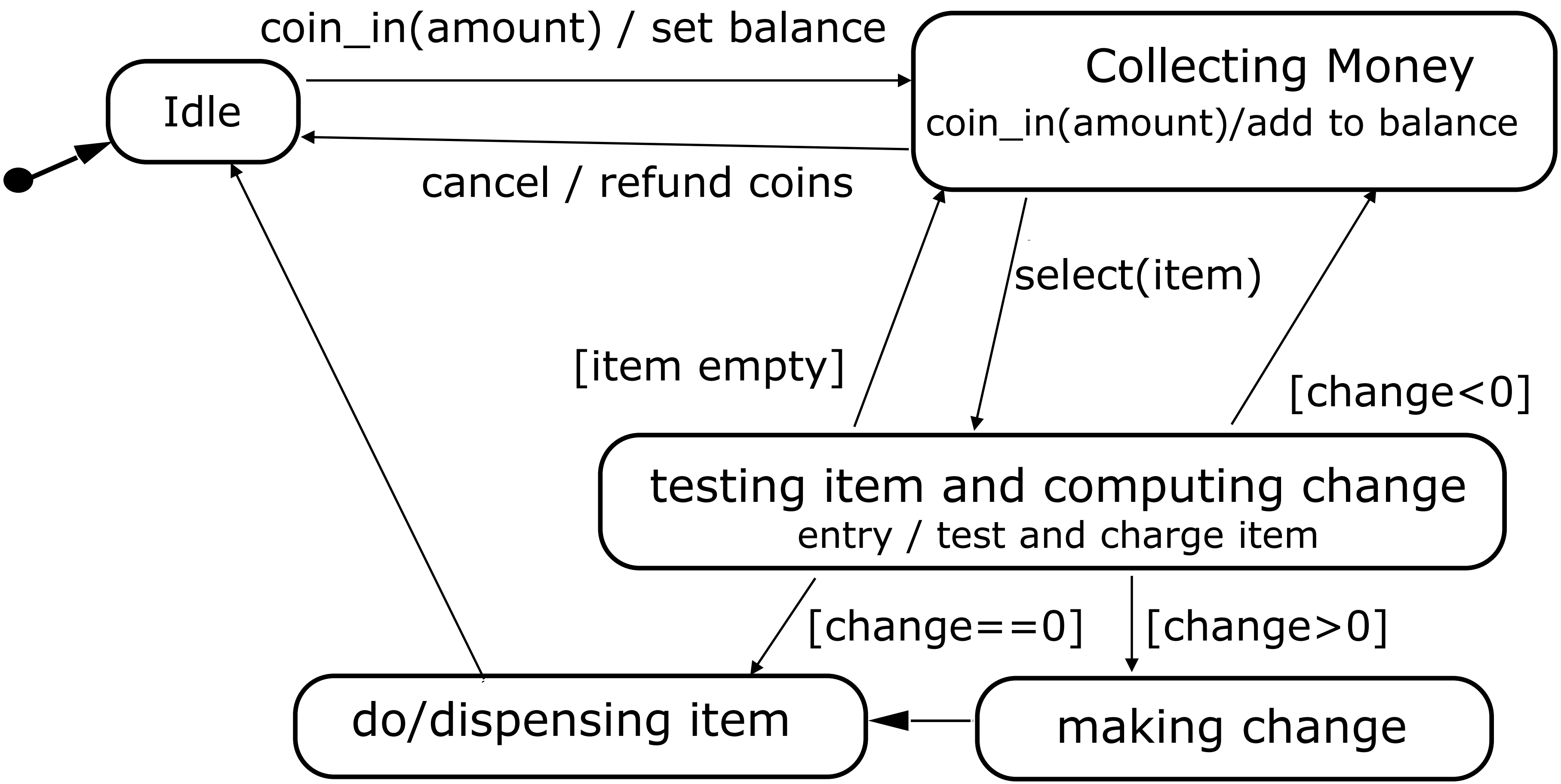
State

- An abstraction of the attribute values of a later implementation class
  - A state describes a certain set of configurations of attribute values in an object (instance)

- Basically an "appropriate" equivalence class of attribute value configurations that need not be distinguished
  - example: the state *"in_active_region"* means
    - `0 < x  &&  x <= 150  &&  100 < y  &&  y <= 150`
  - What is appropriate depends on our current goal

- State has duration

Example of a statechart diagram



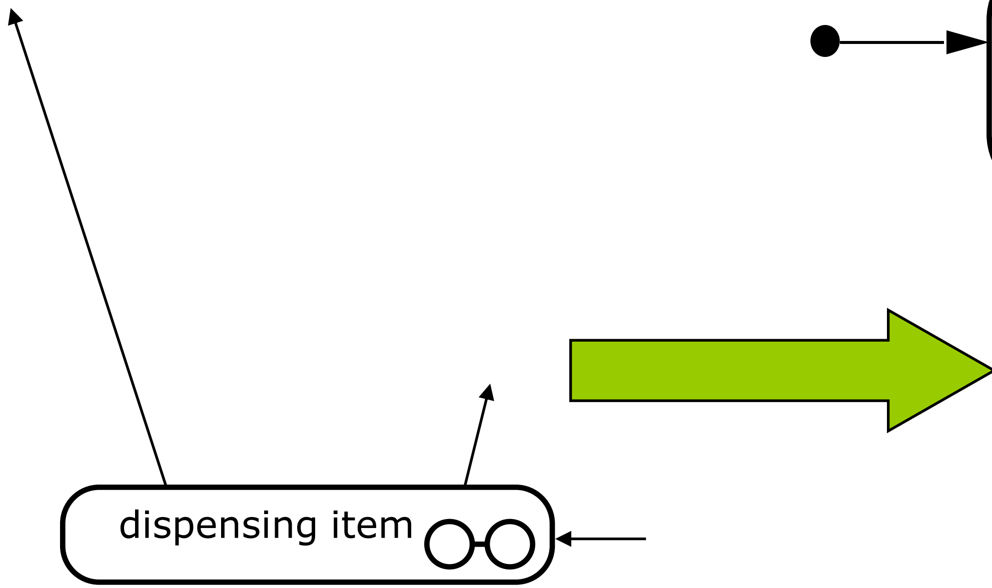
Note some states do not have (nor need) a name,
but need further details

Nested state diagram

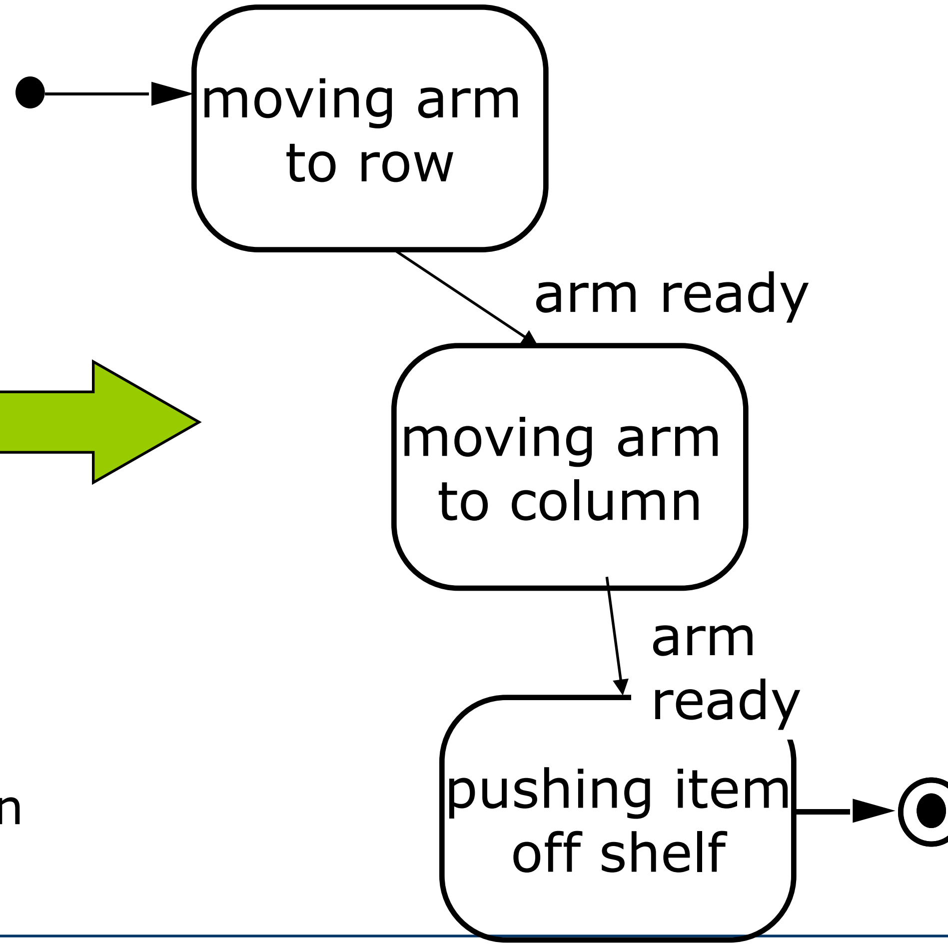
- Activities in states are composite items denoting other lower-level state diagrams
  - which may be spelled out or not
- A lower-level state diagram corresponds to lower-level states and events that are invisible at the higher level
- The set of substates in such a nested state diagram denotes a *composite state*
  - enclosed by a large rounded box, also called region
- Transitions from other states to the composite state enter the initial substate of the composite state
  - Much like the entry point of a subroutine
- Transitions to other states from a composite state are inherited by all the substates (state inheritance)
  - Much like a runtime exception whose occurrence can terminate a method at many points

Example
of a nested statechart diagram

'Dispense item' as
an atomic activity:

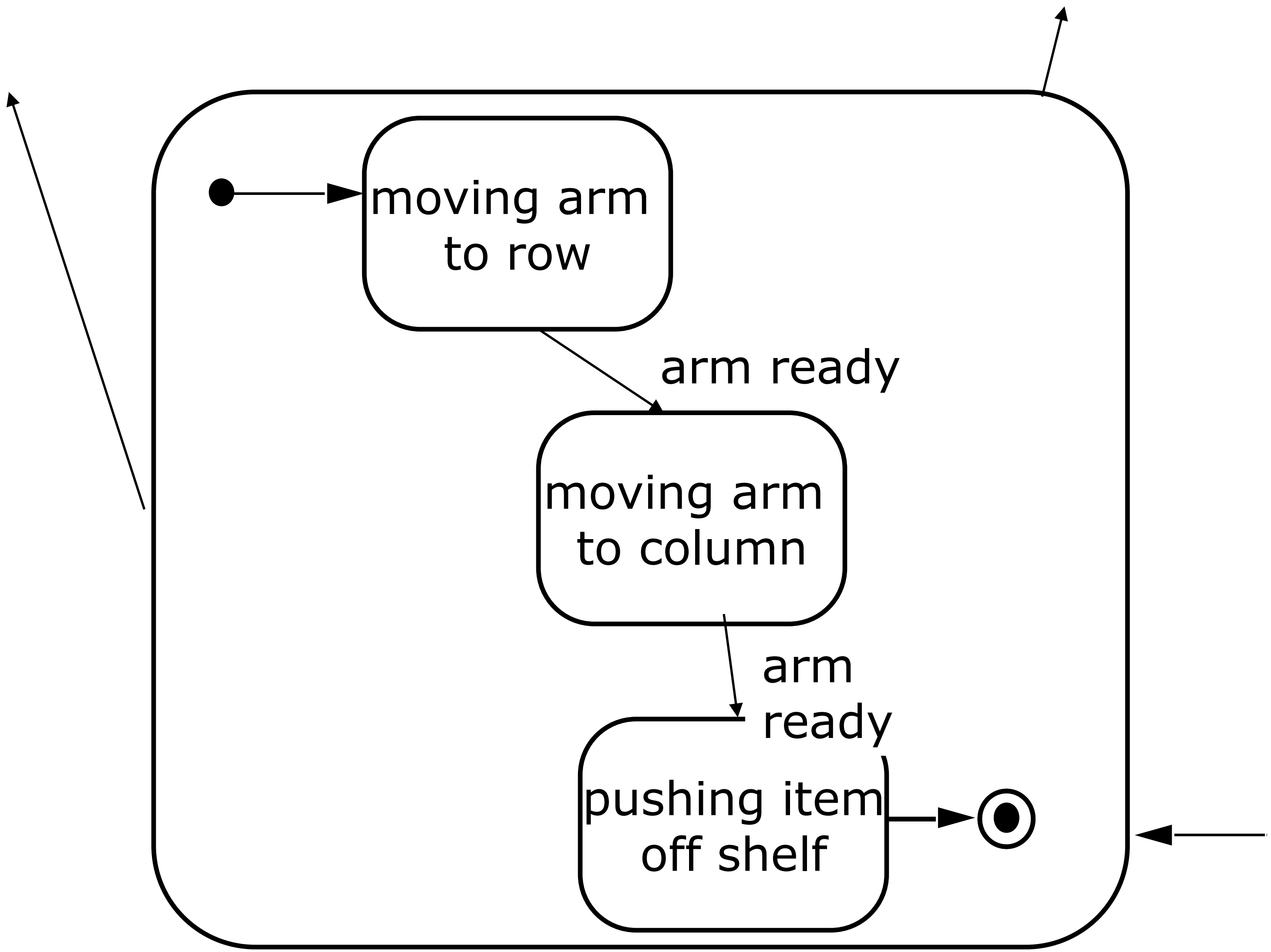


'Dispense item' as
a composite activity:



The little glasses indicate that
there are sub-activities hidden in
this composite activity

Composite State

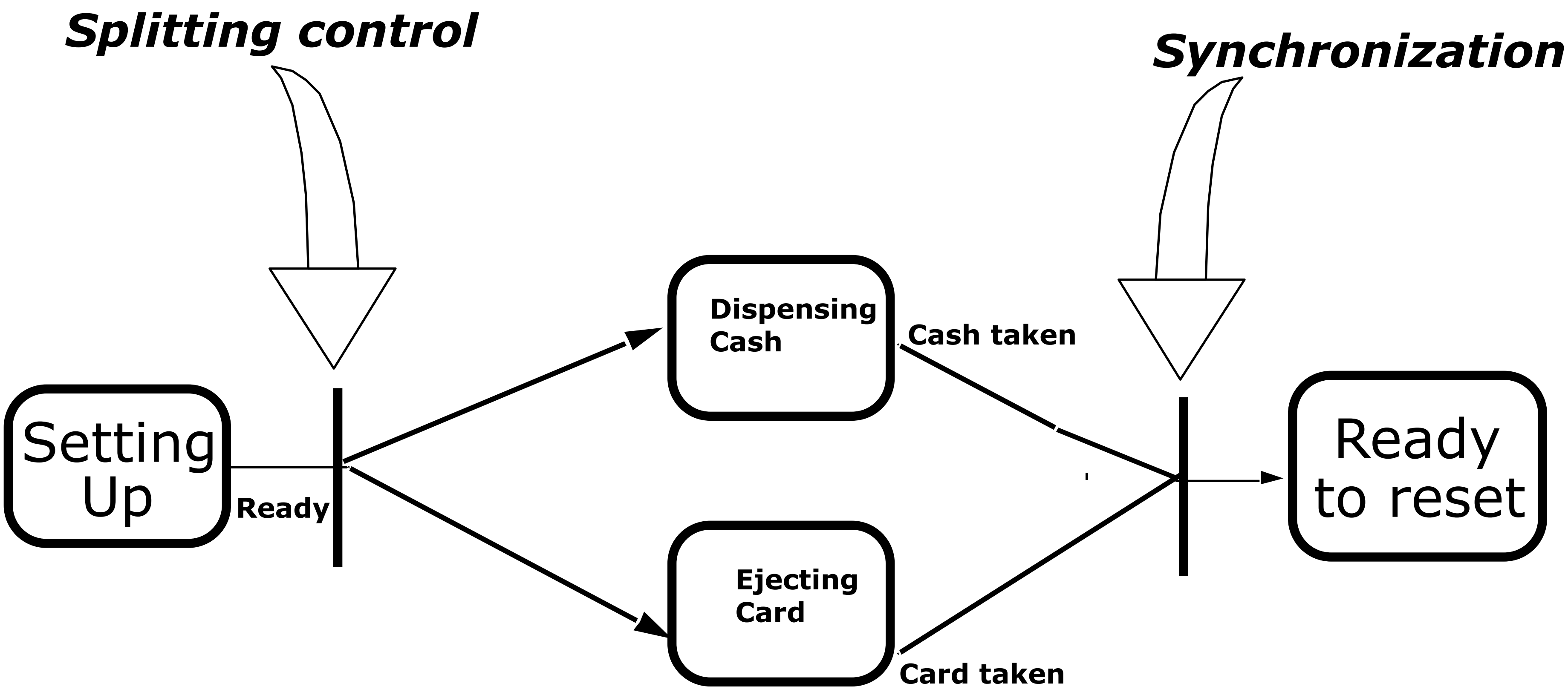


Modeling concurrency

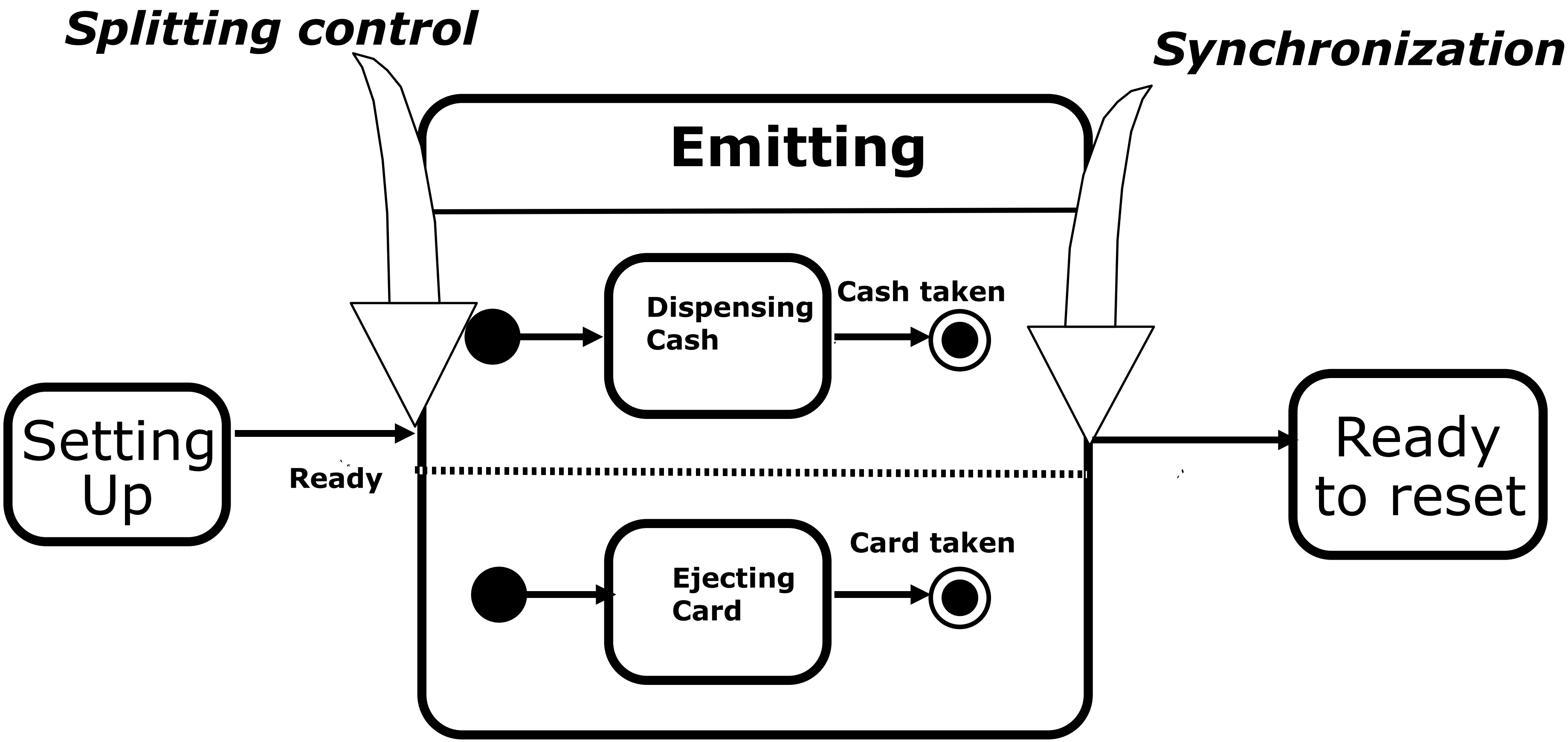
Two types of concurrency:

- 1. System concurrency (across objects)
  - State of overall system as the aggregation of state machines, one for each object
  - Note that one state diagram (for a class) may result in many state machines (one per instance of the class)
  - Each state machine is conceptually executing concurrently with all others
- 2. Object concurrency (within objects)
  - An object can be partitioned into subsets of states (attributes and links) such that each subset has its own subdiagram
  - The state of the object consists of a set of states: one state from each subdiagram
  - State diagrams (or composite states) are divided into *regions* by dotted lines

Example
of concurrency within an object



Using implicit join/split



Dynamic modeling of user interfaces

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- Statechart diagrams can be used for the design of user interfaces
  - to represent the Navigation Path or Page Flow
- States: Name of screens
  - Graphical layout of the screens associated with the states helps when presenting the dynamic model of a user interface
- Activities/actions are shown as bullets under screen name
  - Often only the exit action is shown
- State transitions: Result of exit action
  - Button click
  - Menu selection
  - Cursor movements
- Good for web-based user interface design

Simplified navigation path example

Diagnostics Menu
- User moves cursor to Control Panel or Graph

Control panel
- User selects functionality of sensors

Graph
- User selects data group and type of graph

Define
- User defines a sensor event from a list of events

Enable
- User can enable a sensor event from a list of sensor events

Disable
- User can disable a sensor event from a list of sensor events

Selection
- User selects data group
  - Field site
  - Car
  - Sensor group
  - Time range
- User selects type of graph
  - time line
  - histogram
  - pie chart

List of events
- User selects event(s)

List of sensor events
- User selects sensor event(s)

Visualize
- User views graph
- User can add data groups for being viewed

Link
- User makes a link (doclink)

(lines represent pairs of arrows in both directions)

[8]

Practical tips for state chart modeling

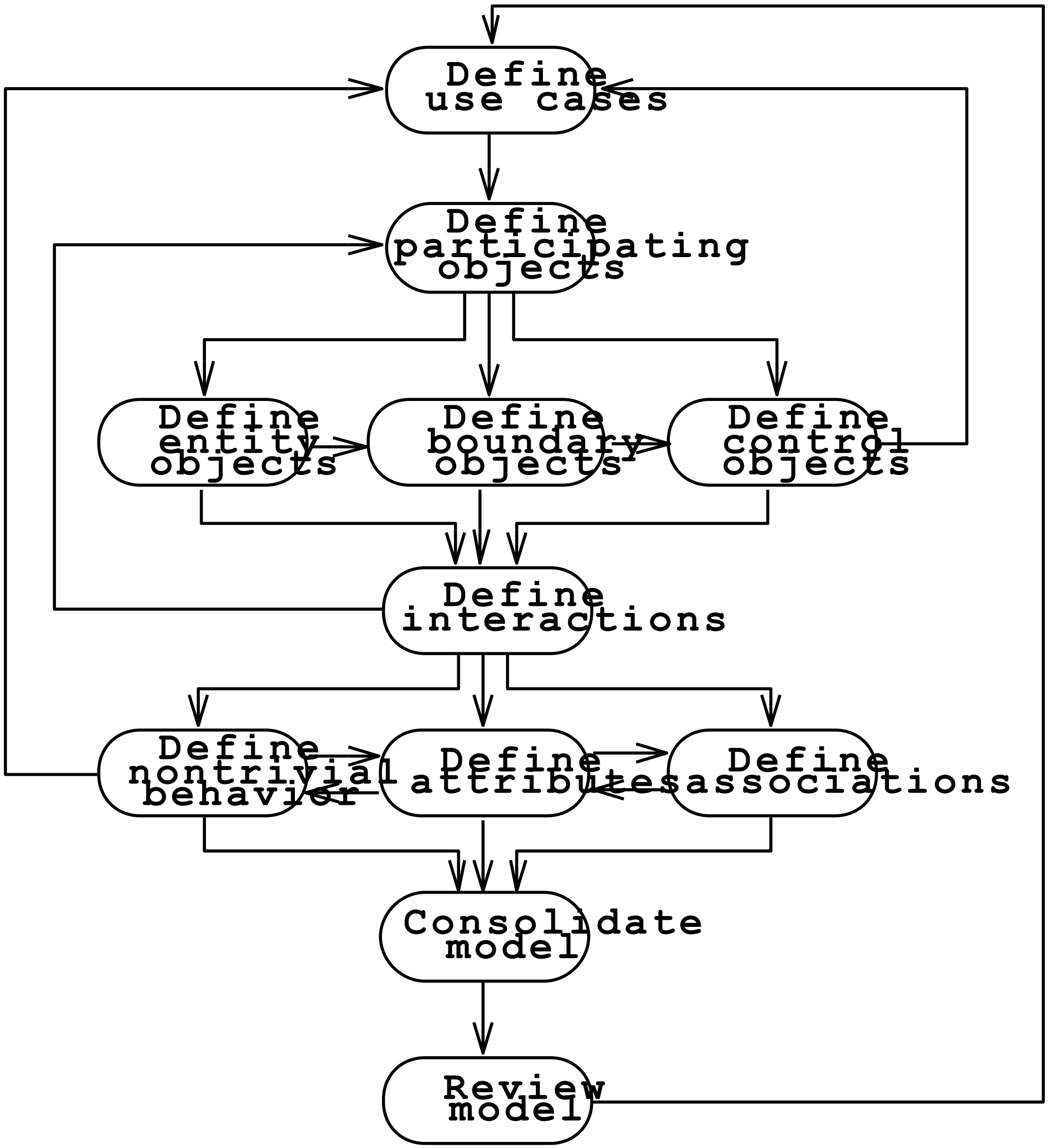
- Construct dynamic models only for classes with significant (complex/important) dynamic behavior
  - Avoid "analysis paralysis"
  - Exception: If state diagrams suffice for code generation
    - Typically for control logic, e.g. in telecommunications systems
- Consider only relevant attributes when defining states
  - Use abstraction heavily
- Look at the granularity of the application when deciding on actions and activities
  - This is still analysis, not design!

- Reduce notational clutter
  - Try to put actions into state boxes (look for identical actions on events leading to the same state)

Summary: requirements analysis

1. What is the external behavior? → **Functional Modeling**
   - Create scenarios and use case diagrams
     - Talk to client, observe, get historical records, do thought experiments
2. What is the structure of the system? → **Object Modeling**
   - Create *class diagrams*
     - Identify objects
     - What are the associations between them? Multiplicity?
     - What are the attributes of the objects?
     - What operations are defined on the objects?
3. What is its behavior? → **Dynamic Modeling**
   - Create *sequence diagrams*
     - Identify senders and receivers
     - Show sequence of events exchanged between objects
     - Identify event dependencies and event concurrency
   - Create *state diagrams*
     - Only for the dynamically interesting objects

Analysis: UML activity diagram



Note that this diagram is rather vague, as the meaning of the arrows is not explained

[8]

When is a model dominant?

- We call a model dominant if it contains a much larger fraction of the interesting information than the others

Examples:

- Simple database system:
  - Situation: The operations are straightforward (load, store), but there are complex data structures
  - Consequence: The static object model is dominant
- Telephone switching system:
  - Data structures do not tell us much and behavior is too complex to be fully described by use cases
  - The dynamic model (in particular using statecharts) is dominant

Requirements analysis document template

1. Introduction
2. Current system
3. Proposed system
   - 3.1 Overview
   - 3.2 Functional requirements [keep this short! →3.5.2]
   - 3.3 Nonfunctional requirements
   - 3.4 Constraints ("Pseudo requirements") *see the following slides*
   - 3.5 Analysis Model *on 3.5 (short), 3.3, 3.4*
     - 3.5.1 Scenarios
     - 3.5.2 Use case model
     - 3.5.3 Object model
       - 3.5.3.1 Data dictionary
       - 3.5.3.2 Class diagrams
     - 3.5.4 Dynamic model
     - 3.5.5 User interface
4. Glossary

Section 3.5: system models

- 3.5.1 Scenarios
  - As-is scenarios, visionary scenarios
- 3.5.2 Use case model
  - Actors and use cases
- 3.5.3 Object model (this is still analysis!)
  - Data dictionary
  - Class diagrams (classes, associations, attributes and operations)
- 3.5.4 Dynamic model
  - State diagrams for classes with significant dynamic behavior
  - Sequence diagrams for collaborating objects (protocol)
- 3.5.5 User Interface
  - Navigational Paths, Screen mockups

Section 3.3: nonfunctional requirements

- 3.3.1 User interface and human factors
- 3.3.2 Documentation
- 3.3.3 Hardware considerations
- 3.3.4 Performance characteristics
- 3.3.5 Error handling and extreme conditions
- 3.3.6 System interfacing
- 3.3.7 Quality issues
- 3.3.8 System modifications
- 3.3.9 Physical environment
- 3.3.10 Security issues
- 3.3.11 Resources and management issues

see the following slides

Nonfunctional requirements: trigger questions

- 3.3.1 User interface and human factors
  - What type of user will be using the system?
  - Will more than one type of user be using the system?
  - What sort of training will be required for each type of user?
  - Is it particularly important that the system be easy to learn?
  - Must users be particularly well protected from making errors?
  - What sort of UI input/output devices will be used?
- 3.3.2 Documentation
  - What kind of documentation is required?
  - What audience is to be addressed by each document?
- 3.3.3 Hardware considerations
  - What hardware is the proposed system to be used on?
  - What are the characteristics of the target hardware, including memory size and auxiliary storage space?

Nonfunctional requirements (2)

- 3.3.4 Performance characteristics
  - Are there any speed, throughput, or response time constraints on the system?
  - Are there size or capacity constraints on the data to be processed by the system?

- 3.3.5 Error handling and extreme conditions
  - How should the system respond to input errors?
  - How should the system respond to extreme conditions?

- 3.3.6 System interfacing
  - Is input coming from systems outside the proposed system?
  - Is output going to systems outside the proposed system?
  - Are there restrictions on the format or medium that must be used for input or output?

Nonfunctional requirements (3)

- 3.3.7 Quality issues
  - What are the requirements for reliability?
  - Must the system trap faults?
  - How fast must the system restart after a failure?
  - What is the acceptable system downtime per day/month/year?
  - Is it important that the system be portable (able to move to different hardware or operating system environments)?

- 3.3.8 System Modifications
  - What parts of the system are likely candidates for later modification?
  - What sorts of modifications are expected?

- 3.3.9 Physical Environment
  - For example, unusual temperatures, humidity, vibrations, magnetic fields, ...

Nonfunctional requirements (4)

- 3.3.10 Security Issues
  - Must access to any data or the system itself be controlled?
  - Is physical security an issue?

- 3.3.11 Resources and Management Issues
  - How often will the system be backed up?
  - Who will be responsible for
    - system installation?
    - daily operation and configuration?
    - back up? When? How often?
    - maintenance?
  - What is the desaster recovery plan?

Constraints (pseudo requirements)

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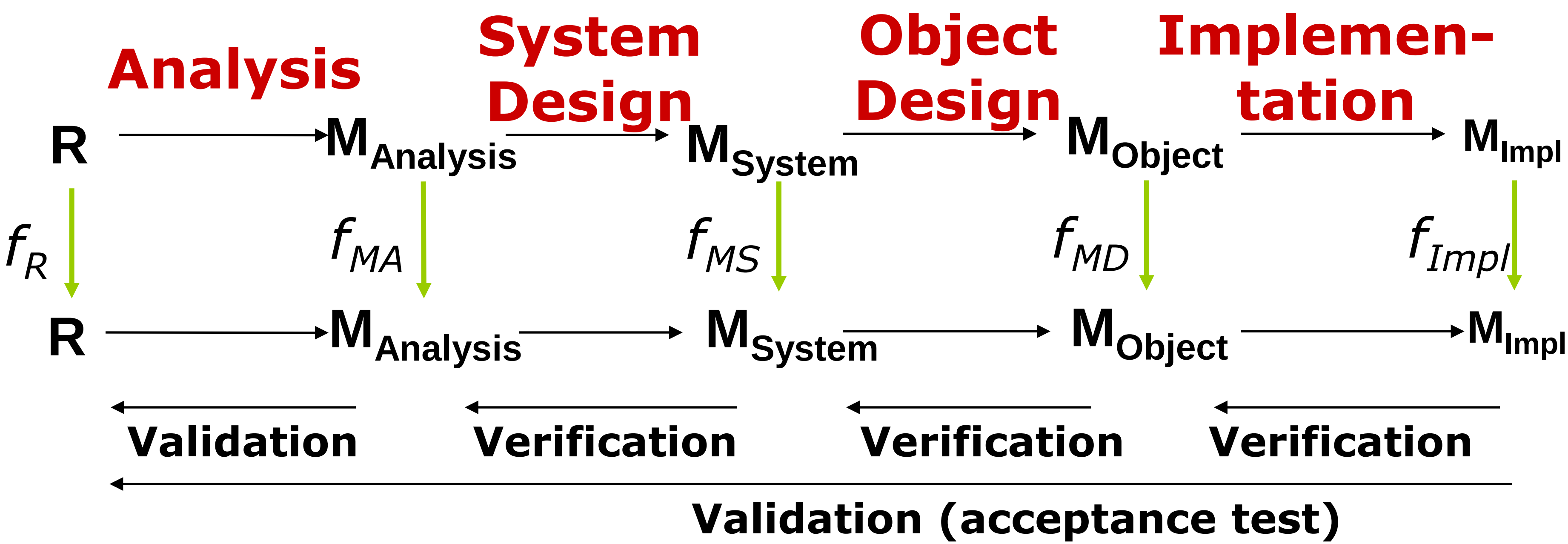
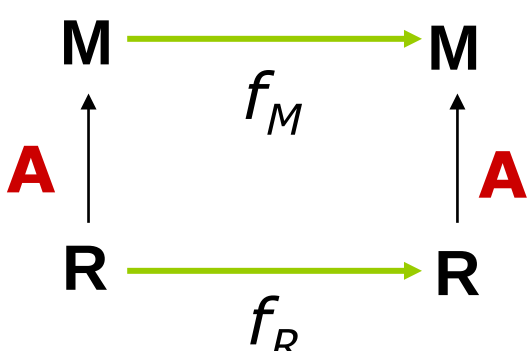
- Constraint:
  - Any client restriction on the solution domain

- Examples:
  - The target platform must be an IBM iSeries
  - The implementation language must be COBOL
  - The documentation standard X must be used
  - A dataglove must be used
  - ActiveX must not be used
  - The system must interface to a papertape reader

Verification and validation of models





M = Model

R = Reality

f = Behavior/relationships

A = abstraction/modelling

Correctness, completeness and consistency

- Verification is an equivalence check between two related models:
  - The second was derived from the first by transformation. Is the transformation correct?
- Validation is different. We don’t have two models, we need to compare one model with reality
  - "Reality" can also be an artificial system, like a legacy system

- Requirements and implementations should be validated with the client and the user
  - Techniques for requirements: Formal and informal reviews (Meetings, requirements review)
  - Techniques for implementations: Acceptance testing
- Requirements validation involves the checks for
  - Correctness, Completeness, Ambiguity, Realism

Modeling checklist for the review

- Is the model correct?
  - A model is correct if it represents the client's view of the the system: Everything in the model represents an aspect of reality
- Is the model complete?
  - Every relevant scenario, including exceptions, is described
- Is the model consistent?
  - The model does not have components that contradict each other (for example, deliver contradicting results)
- Is the model unambiguous?
  - The model describes one system (one reality), not many
- Is the model realistic?
  - The model can be implemented with acceptable effort

At the end of analysis: Project agreement

- The project agreement represents the acceptance of (parts of) the analysis model (as documented by the requirements analysis document) by the client

- The client and the developers converge on a single idea and agree about the functions and features that the system will have. In addition, they agree on:
  - a list of prioritized requirements
  - a revision process
  - a list of criteria that will be used to accept or reject the system
  - a schedule, and probably a budget

Prioritizing requirements

- High priority ("Core requirements")
  - Must be addressed during *analysis, design, and implementation*
  - A high-priority feature must be demonstrated successfully during client acceptance

- Medium priority ("Optional requirements")
  - Must be addressed during *analysis and design*
  - Often implemented and demonstrated in the second iteration of the system development

- Low priority ("Fancy requirements")
  - Must be addressed during *analysis* ("very visionary scenarios")
  - Illustrates how the system may be going to be used in the future
    - e.g. once not-yet-available technology becomes available

Summary

In this lecture, we reviewed the construction of the dynamic model from use case and object models.

In particular:

- Sequence and statechart diagrams for identifying new classes and operations
- In addition, we described the requirements analysis document and its components

Thank you!