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# 23. Action-Oriented Design Methods

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1) Action-Oriented Design
2) Structured Analysis/Design (SA/SD)
3) Workflow nets
4) Architectures

# Obligatory Reading

- Balzert, Kap. 14
- Ghezzi Ch. 3.3, 4.1-4, 5.5
- Pfleeger Ch. 4.1-4.4,  5

# 23.1 Action-Oriented Design

# 23.1 Action-Oriented Design

- Action-oriented design is similar to function-oriented design, but admits that the system has states.
  - It asks for the internals of the system
  - Actions require state on which they are performed (imperative, state-oriented style)
  - Actions are running in parallel
- Decomposition strategy:
  - Divide: finding subactions
  - Conquer: grouping to modules and processes
  - Result: reducible action system
- Example: all function-oriented design methods can be made to action-oriented ones, if state is added

**What are the actions the system should perform?**

**What are the subactions of an action?**

**Which state does an action change?**

# 23.2 Action-Oriented Design with SA/SD

Data-flow connects processes (parallel actions)

State is implicit in the atomic processes, not explicit in the global, architectural specifications

# Structured Analysis and Design (SA/SD)

- A specific variant of action-oriented design is process-oriented design (data-flow based design)
  - [DeMarco, T. Structured Analysis and System Specification, Englewood Cliffs: Yourdon Press, 1978]

- Notations of SA:
  - ***Function trees*** (action trees, process trees): decomposition of system functions
  - ***Data flow diagrams (DFD)***, in which the actions are called *processes*
  - ***Data dictionary*** (context-free grammar) describes the structure of the data that flow through a DFD

- Alternatively, class diagrams can be used
  - Pseudocode (minispecs) describes central algorithms (state-based)
  - Decision Table and Trees describes conditions (see later)

# Why SA is Important

- Usually, action-oriented design is *structured*, i.e., based on hierarchical stepwise refinement.
- Resulting systems are
  - *reducible*, i.e., all results of the graph-reducibility techniques apply.
  - *parallel*, because processes talk with streams
- SA and SADT are important for *embedded systems* because resulting systems are parallel and hierarchic
- **Mashups** are web-based data-flow diagrams and can be developed by SA (see course Softwarewerkzeuge)

# Structured Analysis and Design (SA/SD) – The Development Process

On the highest abstraction level, on the **context diagram**:

- **Elaboration**: Define interfaces of entire system by a top-level action tree
- **Elaboration**: Identify the input-output streams most up in the action hierarchy
- **Elaboration**: Identify the highest level processes
- **Elaboration**: Identify stores

**Refinement**: Decompose function tree hierarchically

**Change Representation**: transform action tree into process diagram (action/data flow)

**Elaboration**: Define the structure of the flowing data in the Data Dictionary

**Check consistency** of the diagrams

**Elaboration**: Minispecs in pseudocode

# Data-Flow Diagrams (Datenflussdiagramme, DFD)

DFD are a special form of Petri nets (see Chapter on PN)

They are also special workflow languages without repository and global state

- DFD use local stores for data, no global store
- Less conflicts on data for parallel processes

Good method to model parallel systems

# DFD-Modeling

Reducible (hierarchic) nets of processes linked by channels (streams, pipes)

**Context diagram:** top-level, with terminators

Parent diagrams, in which processes are point-wise refined

Child diagrams are refined processes

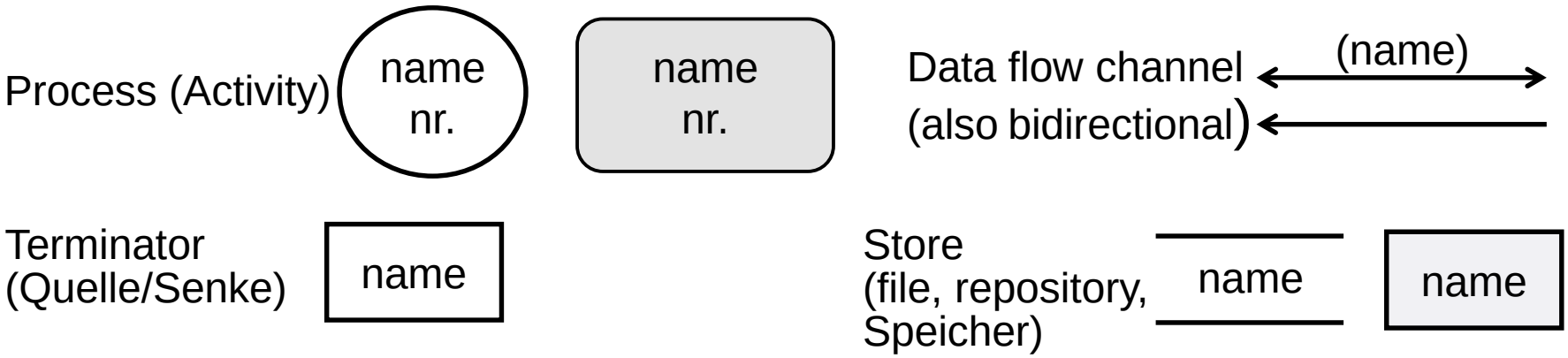
Refinement can be syntactic or semantic

Data dictionary contains types for the data on the channels

Mini-specs (Minispezifikationendienen) specify the atomic processes and their transformationen

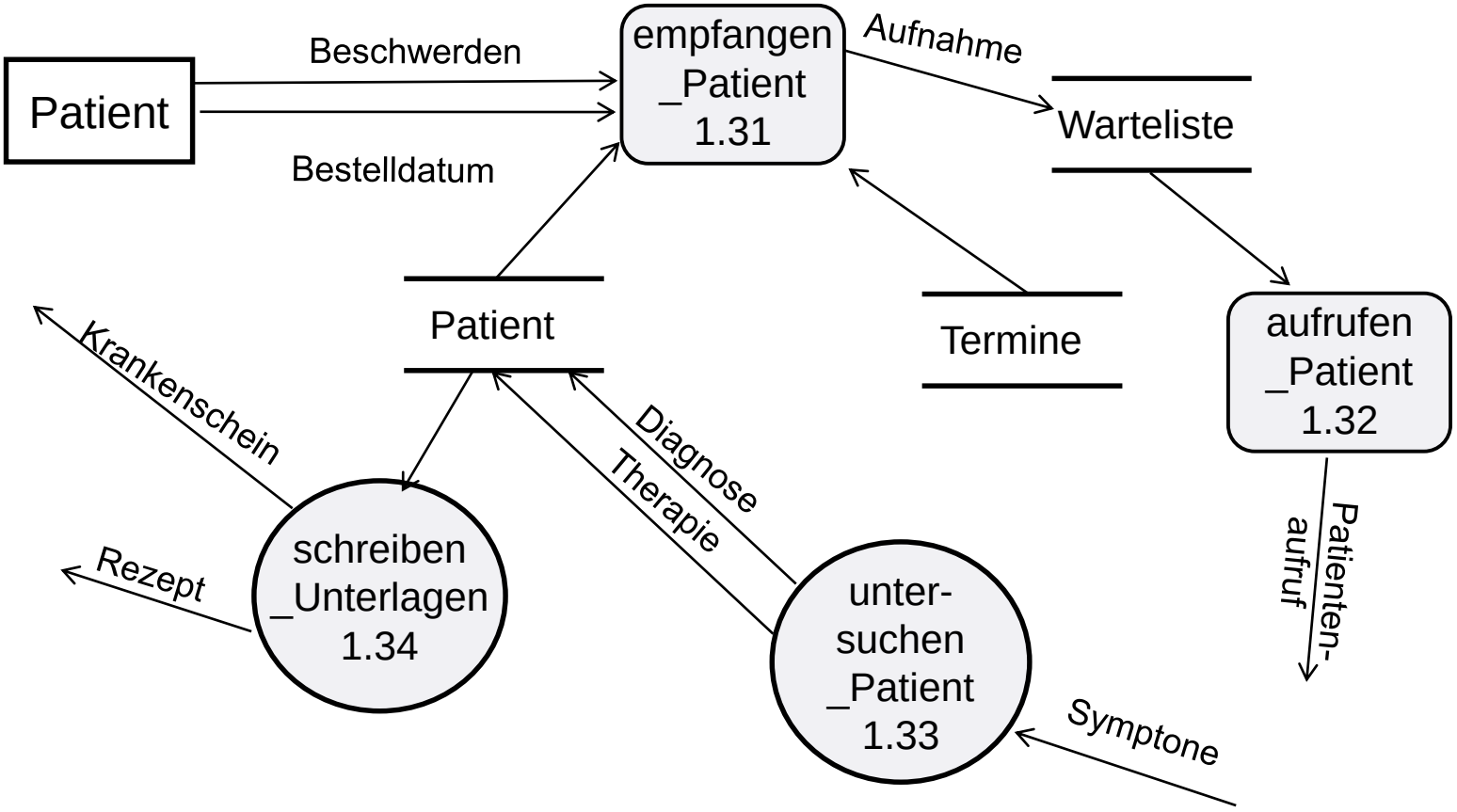
— with Pseudocode or other high-level langauges

**Symbole (Balzert/UML):**



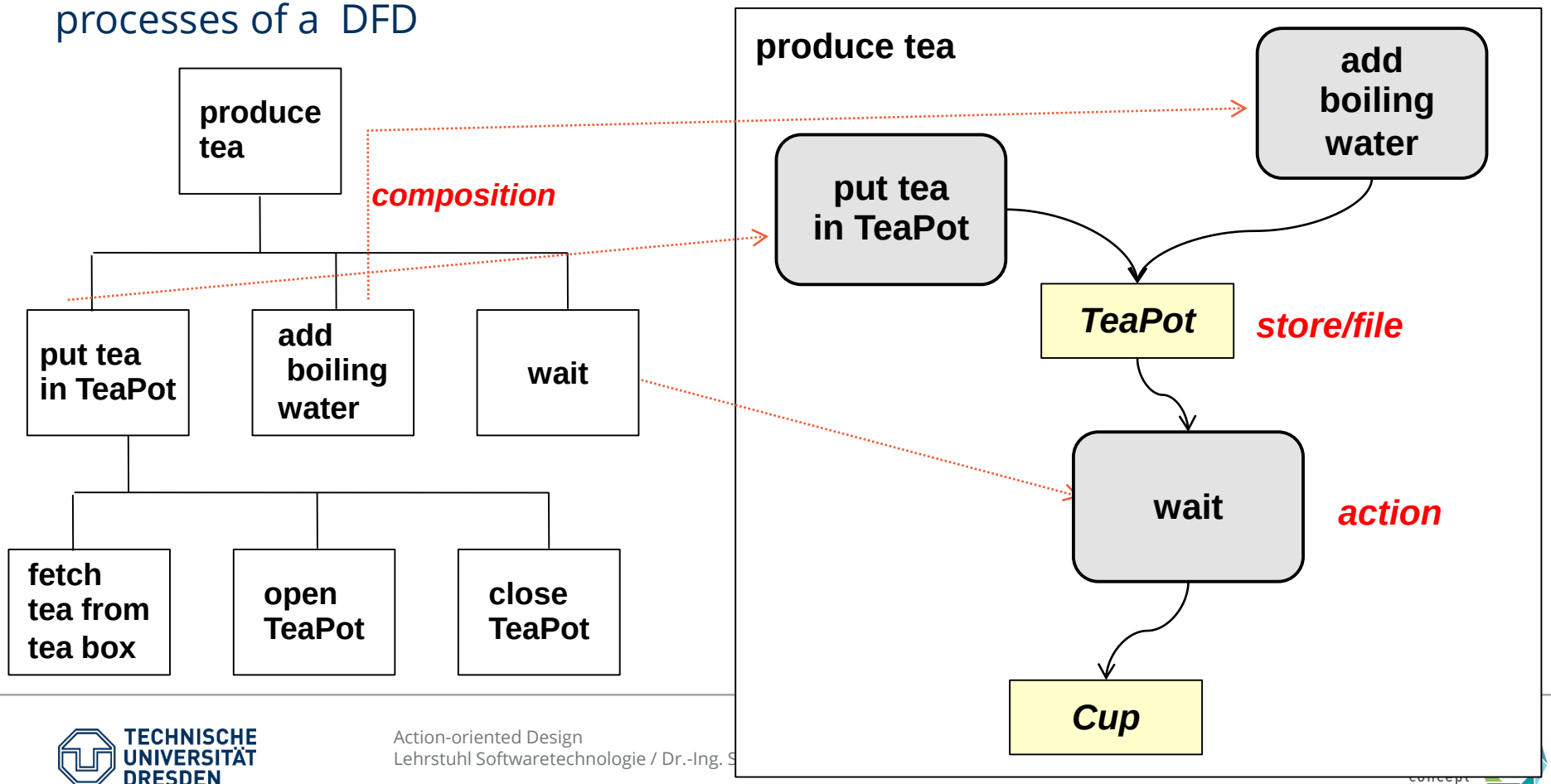
# Ex.: DFD "treat_Patient"

UML uses ovals for activities; SA uses circles



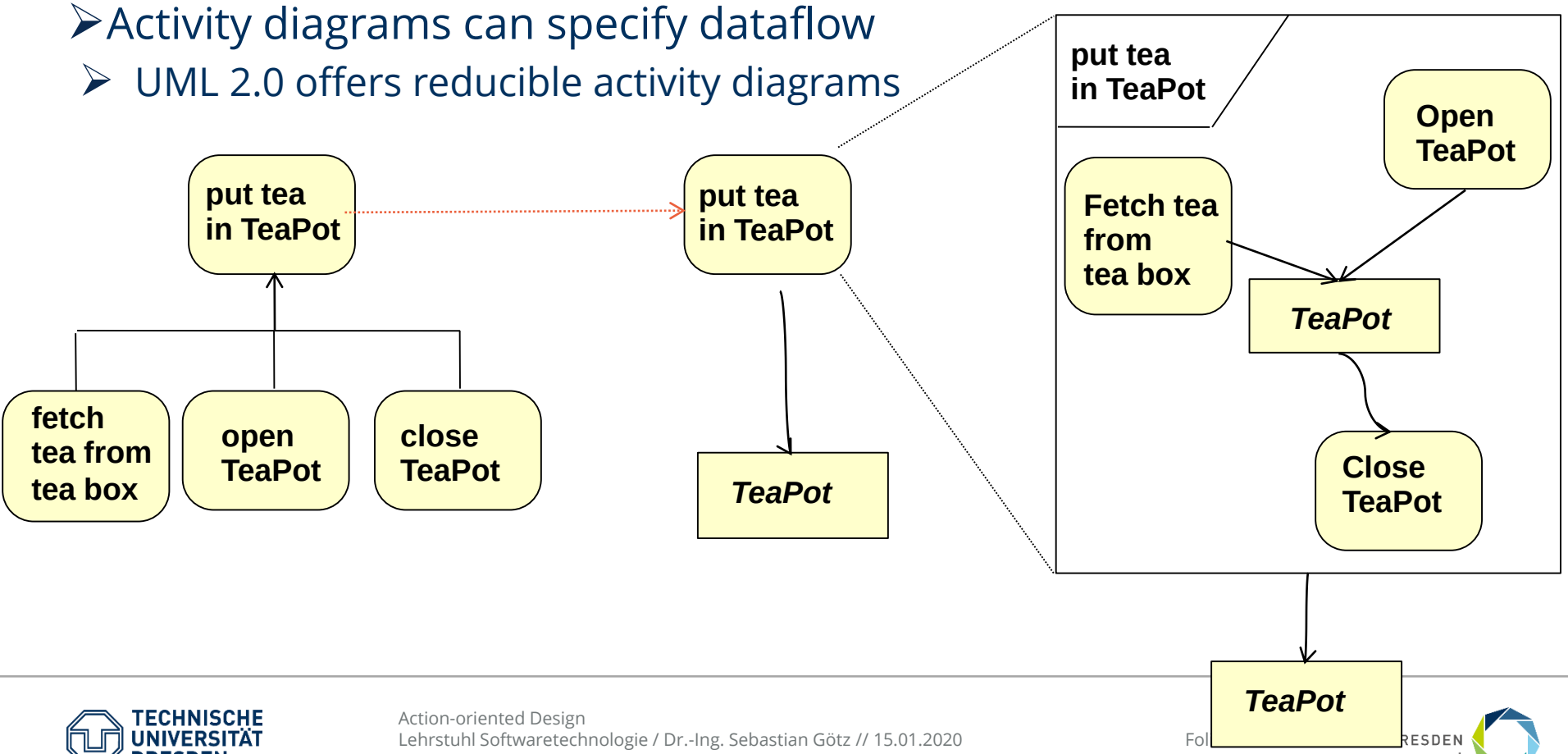
# Action Trees and DFDs

- Action trees can be derived from function trees
- DFD are homomorphic to Action trees, but add stores and streams
- **RepresentationChange**: Construct an action tree and transform it to the processes of a DFD



# Pointwise Refinement of Actions

- Subtrees in the function tree lead to reducible subgraphs in the DFD
- UML action trees can be formed from activities and aggregation
- Activity diagrams can specify dataflow
  - UML 2.0 offers reducible activity diagrams



# Typing Edges with Types from the Data Dictionary

➢In an SA, the **data dictionary** collects data types describing the context free structure of the data flowing over the edges

- Grammar: For every edge in the DFDs, the context-free grammar contains a non-terminal that describes the flowing data items
- UML class diagram: classes describe the data items

➢Grammars are written in Extended Backus-Naur Form (EBNF) with the following rules:

| Notation | Meaning | Example | |
|---|---|---|---|
| | ::= or = | Consists of | A ::= B. |
| Sequence | + | Concatenation | A ::= B+C. |
| Sequence | <blank> | Concatenation | A ::= B C. |
| Selection | I or [ \| ] | Alternative | A ::= [ B \| C ]. |
| Repetition | { }^n | | A ::= { B }^n. |
| Limited repetition m | { } n | Repetition from m to n | A ::= 1{ B }10. |
| Option | ( ) | Optional part | A ::= B (C). |

# Example Grammar in Data Dictionary

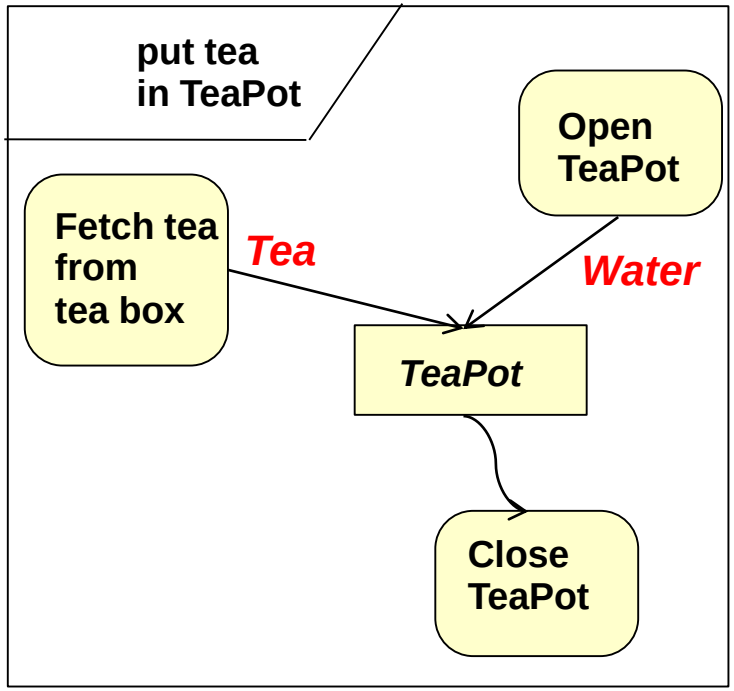
Describes types for channels

```
DataInPot ::= TeaPortion WaterPortion.
TeaAutomatonData ::= Tea | Water | TeaDrink.
Tea ::= BlackTea | FruitTea | GreenTea.
TeaPortion ::= { SpoonOfTea }.
SpoonOfTea ::= Tea.
WaterPortion ::= { Water }.
```

Exc: Read every rule aloud!

# Adding Types to DFDs

- Nonterminals from the data dictionary become types on flow edges
- Alternatively, classes from a UML class diagram can be annotated



# Minispecs in Pseudocode

- **Minispecs** describes the processes in the nodes of the DFD in pseudo code. They describe the data transformation of every process
- Here: specification of the minispec attachment process:

```
procedure: AddMinispecsToDFDNodes
target.bubble := select DFD node;
do while target-bubble needs refinement
   if target.bubble is multi-functional
          then decompose as required;
                  select new target.bubble;
                       add pseudocode to target.bubble;
          else no further refinement needed
   endif
enddo
end
```

# Good Languages for Pseudocode

- SETL (Schwartz, New York University)
  - Dynamic sets, mappings, Iterators
  - http://en.wikipedia.org/wiki/SETL
  - http://randoom.org/Software/SetlX
- PIKE (https://pike.lysator.liu.se/)
  - Dynamic arrays, sets, relations, mappings
  - Iterators
- ELAN (Koster, GMD Berlin)
  - Natural language as identifiers of procedures
  - http://en.wikipedia.org/wiki/ELAN_(programming_language)
  - One of the sources of our TUD OS L4: http://os.inf.tu-dresden.de/L4/l3elan.html
- Smalltalk (Goldberg et.al, Parc)
- Attempto Controlled English (ACE, Prof. Fuchs, Zurich)
  - A restricted form of English, easy to parse

# Structured Analysis and Design (SA/SD) - Heuristics

Consistency checks

- Isomorphism rule between diagrams (e.g., between function trees and DFD)
- Corrections necessary in case of structure clash between input and output formats

Verification

- Point-wise refinement can be proven to be correct by bisimulations of the original and refined net

Advantage of SA

- Hierarchical refinement: The actions in the DFD can be refined, I.e., the DFD is a reducible graph
- SA leads to a hierarchical design (a component-based system)

# Difference to Functional and Modular Design

SA focusses on actions (parallel activities, processes), not functions
- Describe the data-flow through a system
- Describe stream-based systems with pipe-and-filter architectures

Actions are parallel processes
- SA and SADT can easily describe parallel systems

Function trees are interpreted as action trees (process trees) that treat streams of data

# Implementation Hints

Channels (streams): implement with Design Pattern Channel (ST-1)

Processes:

— Ada-82-03 has parallel processes

If actions should be undone (in interactive editing), or replayed, they can be encapsulated into Command objects (see design patterns Command and Interpreter)

If actions work on a data structure, design pattern Visitor allows for extensible action command objects

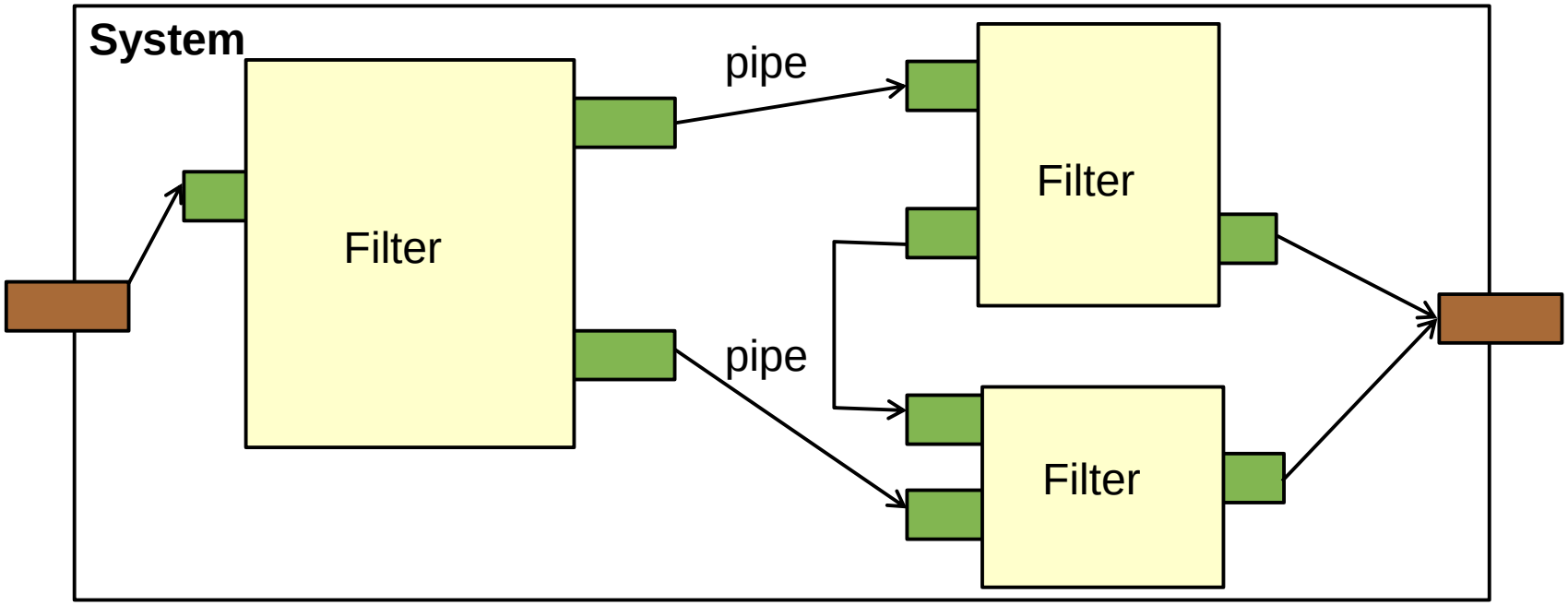
# Result: Data-Flow-Based Architectural Style

SA/SD design leads to dataflow-based architectural style

Processes exchanging streams of data

Data flow forward through the system

Components are called **filters**, connections are **pipes (channels, streams)**



# Application Areas are Manifold

Shell programming with pipes-and-filters
- zsh
- Microsoft Powershell

Image processing systems
- Image operators are filters in image data-flow diagrams

Signal processing systems (DSP-based embedded systems)
- The satellite radio
- Video processing systems
- Car control
- Process systems (powerplants, production control, ...)

Content management systems (CMS)
- Content data is piped through XML operators until a html page is produced

Stream-based business workflows for data-intensive business applications

# 23.3 Workflow Nets

# Obligatory Readings

W.M.P. van der Aalst and A.H.M. ter Hofstede. Verification of workflow task structures: A petri-net-based approach. Information Systems, 25(1): 43-69, 2000.

Web portal “Petri Net World”
http://www.informatik.uni-hamburg.de/TGI/PetriNets/

# Relationship of PN and other Behavioral Models

P.D. Bruza, Th. P. van der Weide. The Semantics of Data-Flow Diagrams. Int. Conf. on the Management of Data. 1989

- https://core.ac.uk/display/23704338

Matthias Weske. Business Process Modeling. Springer-Verlag.

# Workflow Nets

In general, **workflows** are executable sequences of actions, *sharing data* from several repositories or communicating with streams.

**Workflow nets** are reducible with single sources and single sinks (**single-entry/single-exit)**, so that only reducible nets can be specified

- They extend DFD with control flow and synchronization
- They avoid global repositories and global state
- They provide richer operators (AND, XOR, OR) and inhibitor arcs

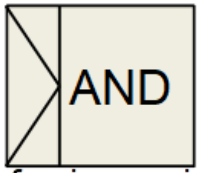
Workflow nets can be compiled to Petri Nets

Further, specialized workflow languages exist, such as

- YAWL Yet another workflow language
- BPMN Business Process Modeling Notation
- BPEL Business Process Execution Language
- For checking of wellformedness constraints, they are reduced to PN

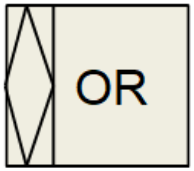
# Complex Transition Operators in Workflow Nets: Join and Split Operators of YAWL

- All incoming places are ready (conjunctive input, AND-join)

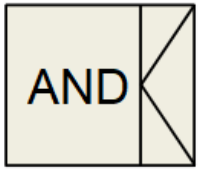



- One out of n incoming places are ready (disjunctive input)


- Some out of n incoming places are ready (selective input)

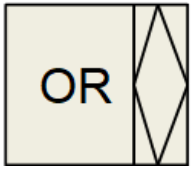



- All outgoing places are filled (conjunctive output, AND-split)



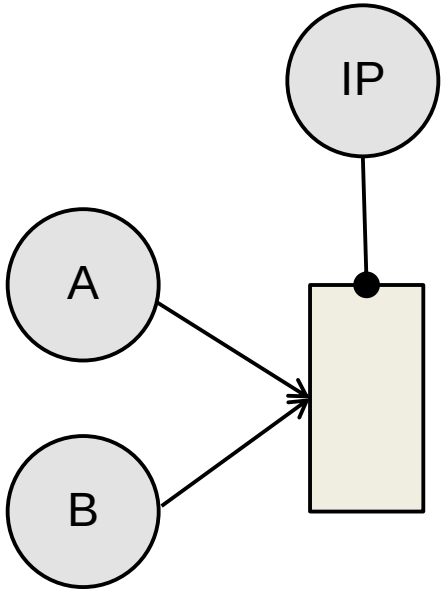

- One out of n outgoing places are filled (disjunctive output)


- Some out of n outgoing places are filled (selective output)



# Inhibitor Arcs

An **inhibitor arc** prevents the firing of an operator or transition

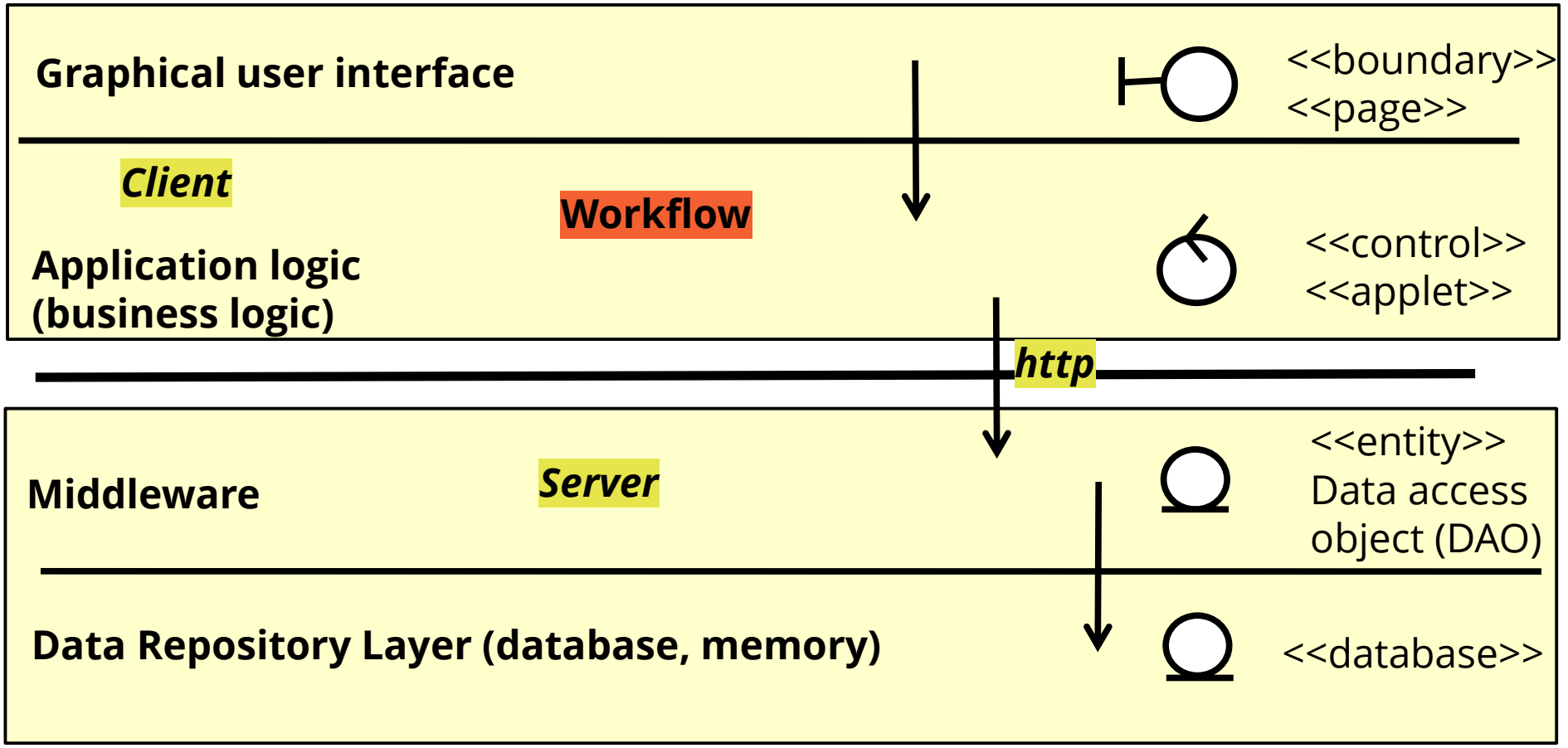



Transition only fires if inhibiting place IP is *not ready*.

# 23.4 Architectures with Workflow Nets

# Rpt. from ST-1: 4-Tier Web System (Thick Client)

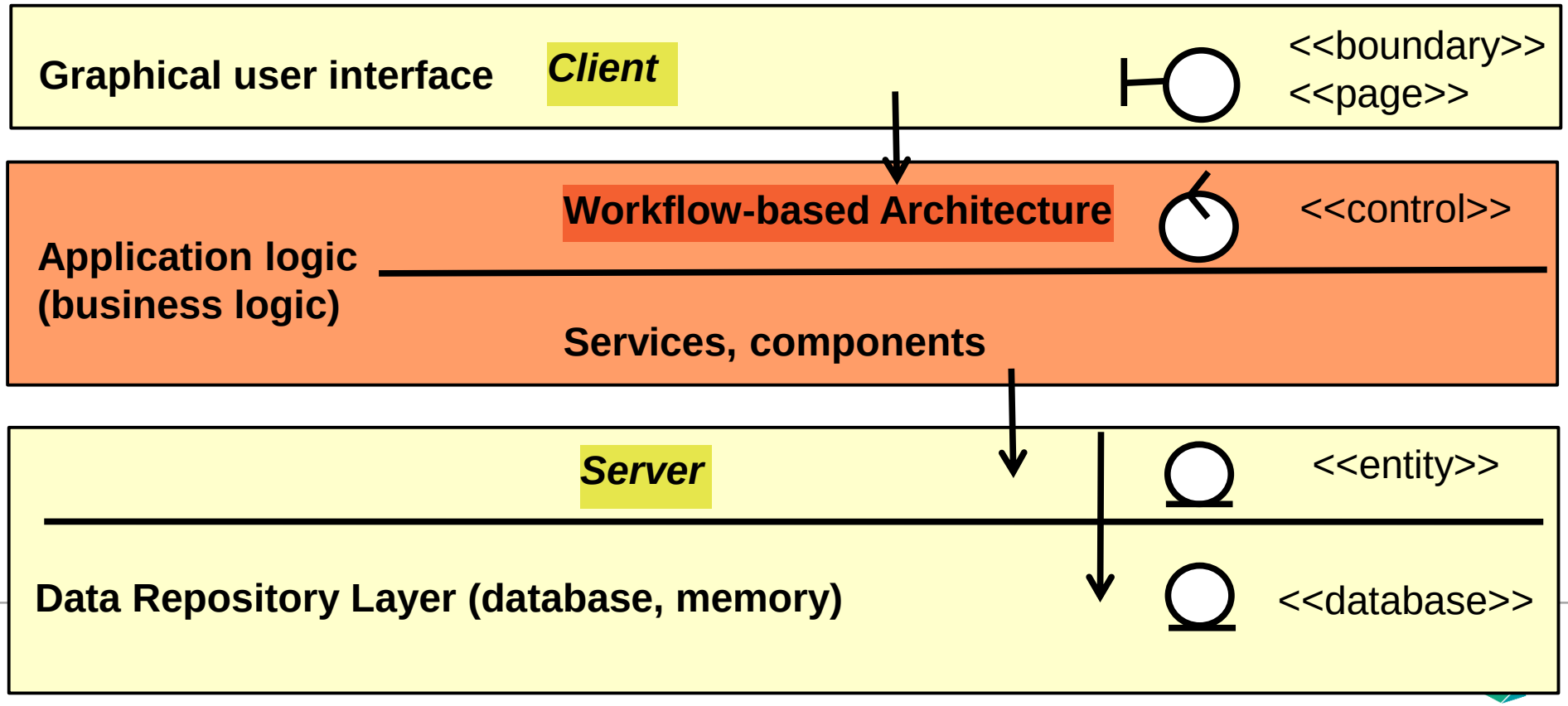
Workflow specifications are for the application logic layer



# 5-Tier with Workflow Language

In a **Workflow Architectural Style**, a workflow in a  language (BPMN, BPEL, WF Nets) specifies the application architecture

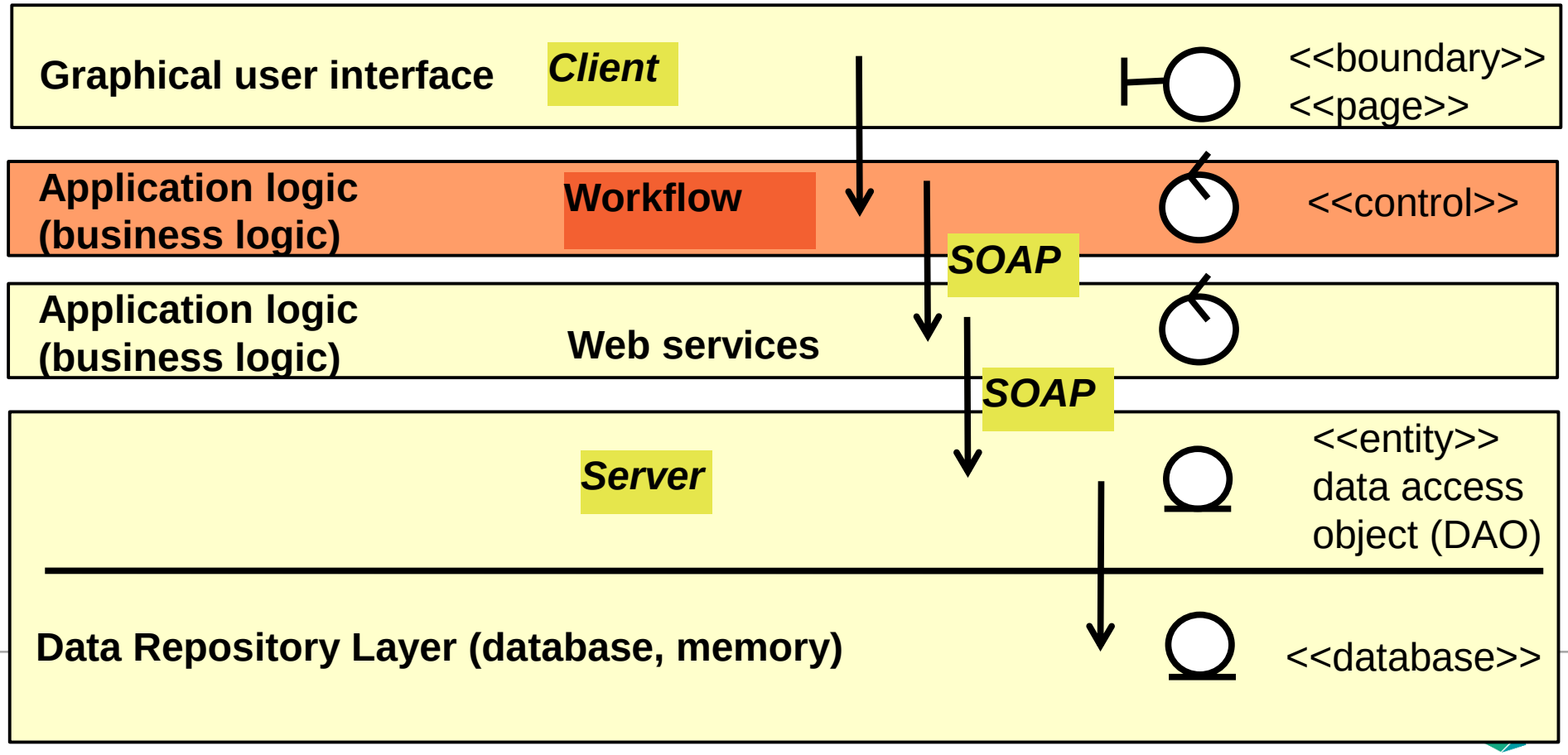
- All services and underlying components are called by the workflow
- The workflow is executed by a special workflow engine



# 5-Tier with Workflow Language and Web Services

Workflow languages (BPMN, BPEL, WF Nets) describe the top-level of the application architecture

— Services and components are called by the workflow via SOAP protocol



# What Have We Learned

Besides object-oriented design, structured, action-oriented design is a major design technique

- It will not vanish, but always exist for certain application areas
- If the system will be based on stream processing, system-oriented design methods are appropriate
- System-oriented design methods lead to reducible systems

Don't restrict yourself to object-oriented design

Workflow languages extend DFD with control flow and can be compiled to Petri nets

In a Workflow-Based Architecture, all services are described by architectural workflows

# End

- Which advantages has the reducibility of the SA DFD specification?
- Show a refinement of a DFD, starting from a given function tree
- Which relation has a DFD and a CPN?
- How would you implement a DFD specification?
- What is the unique characterization of a workflow-based architecture?
- How to extend a workflow net?