Introduction: Processes, information systems, and transition systems

prof.dr.ir. Wil van der Aalst
Outline

• On the relation between processes, systems, and models
• Basic model: Transition systems
• Process models versus object/data models
• Petri nets and other process modeling languages
• Applications/tools
• Process-aware information systems: Trends
On the relation between processes, systems, and models
On the relation between information systems and processes

(a) BP1 BP2 BP3
   IS

(b) BP1
   IS
   BP2 BP3

(c) BP1 BP2 BP3
   IS

(d) BP1
   IS
   BP2
   BP3
Three good reasons for making a process model:

- **gain insight**
  for a better understanding of the system

- **analysis**
  validation and verification

- **specification**
  a blueprint for construction
Basic model: Transition systems

• Any *discrete dynamic system* can be described as a *transition system*.

• Low level model: Mother of all (process) models.

• **Elements:**
  • State
  • Transition
  • State space
  • Transition relation
Discrete dynamic systems

- Y-axis is state space.
- Bullets are transitions (no continuous changes, only discrete ones).
- One possible execution: Transition relation is not described.
Definitions

- A transition system is specified by a pair \((S, \mathcal{TR})\)
  - \(S\) is the state space
  - \(\mathcal{TR} \subseteq S \times S\) is the transition relation
- The elements of \(S\) (state space) are states.
- The elements of \(\mathcal{TR}\) (transition relation) are transitions.

1) Model a light bulb with three states (on, off, broken).
2) Model a queue in a supermarket.
Example: Elevator

• **State space:** $S = \{(\text{floor},\text{direction}) \in \mathbb{IN} \times \{-1,0,1\} \mid (1 \leq \text{floor} \leq 6) \land (\text{floor} = 1) \Rightarrow (\text{direction} \geq 0) \land (\text{floor} = 6) \Rightarrow (\text{direction} \leq 0)\}$

• **Transition relation:** $TR = \{((1,0),(1,1)), ((1,1),(2,1)), ((1,1),(2,0)), \ldots\}$

Describe transition relation formally.
Give graphical representation.
Exercise: Make transition system

• Consider a circular railroad system with 4 tracks (0,1,2,3) and 2 trains (A,B). No two trains should be at the same track at the same time. Trains can only move clockwise.

• Imagine how this would be if there are 50 tracks or more complex rules like claiming the next track or keeping tracks free in-between trains.
Exercise

- Consider two parallel queues in a supermarket
- Describe transition relation formally.
- Give graphical representation.
State explosion problem

50 states

$50^{15} = +/- 30517578125000000000000000000$ states
Large state spaces ...

communication protocol ($10^6$ states)

Figure taken from Frank van Ham
link layer of the IEEE1394 standard (FireWire) simulated using two communication nodes and a bus (25,000 states)
Process models versus object/data models

object/data model

system model = process model + data/object model
Example of a data/object model: A UML class diagram
Other data/object modeling techniques

- Entity-Relationship (ER) diagrams
- Crow’s Foot diagrams
- NIAM/ORM diagrams
Example of a process model: A Petri net modeling order processing

start -> register -> wait_for_availability

register -> reminder

reminder -> receive_payment

receive_payment -> send_bill

send_bill -> archive -> ship_goods

ship_goods -> archive

archive -> archive

archive -> end

end
Other process modeling techniques

- UML activity/statechart diagrams
- Event-driven Process Chains (EPCs)
- IDEF/DFD diagrams
- BPMN/BPEL
- Etc.
Applications of process modeling in concrete products

- Business modeling tools: Protos, ARIS, ...
- Simulation tools: ExSpect, Arena, Simula, ...
- Verification tools: Woflan, ...
- Petri net tools: Design CPN, CPN Tools, ...
- Workflow management systems: Staffware, COSA, MQSeries Workflow, BPM|one, ...
- Enterprise resource planning systems: SAP, Baan, JD Edwards, Oracle, PeopleSoft, ...
- Project planning tools: Microsoft project, ...
- Web services languages: BPML, BPEL4WS, ...
- ...

Business process modeling tools

Protos

Design, communication, (export to) analysis and/or implementation

Based on Petri nets
Business process modeling tools (2)
Business process modeling tools (3)

ARIS

Design, communication, (export to) analysis and/or implementation, import of real data.

Based on EPCs
Business process modeling tools (4)

SAP reference model (>600 EPCs)
Business process modeling tools (5)
Simulation tools

**ExSpect**

Rapid prototyping, performance analysis, validation, gaming.

Based on Petri nets.
Simulation tools (2)
Verification tools

**Woflan**

Detecting errors.

Based on Petri nets.
Process Mining tools (1)
Process mining tools (2)
Petri net tools

CPN Tools

Design and analysis

Based on Petri nets.
Workflow management systems

Staffware workflow designer
Workflow management systems (2)

**Staffware worklist handler**

Based on a vendor specific language.

**Enactment**
Workflow management systems (3)

COSA

Enactment

Based on Petri nets.
Workflow management systems (4)
Enterprise resource planning (ERP) systems

Baan (DEM)

Design, training, configuration, and enactment

Based on Petri nets.
Enterprise resource planning (ERP) systems (2)

SAP (workflow)

Design, training, configuration, and enactment

Also EPC view
Project planning

MS project

Planning

cf. PERT/CPM
Web services

**Oracle BPEL**

**Enactment based on BPEL standard**

```
<sequence name="main"> <!-- Receive input from requestor. Note: This maps to operation defined in CFP23_flow.wsdl -->
  <receive name="receiveInput" partnerLink="client" portType="client:CFP23_flow" operation="process" variable="inputVariable" createInstance="yes"/> <!-- Generate reply to synchronous request -->
  <assign name="Assign_4">
    <copy>
      <from variable="inputVariable" part="payload" query="/client:CFP23_flowProcessRequest/client:input"/>
      <to variable="outputVariable" part="payload" query="/client:CFP23_flowProcessResponse/client:result"/>
    </copy>
  </assign>
  <flow name="Flow_1">
    <sequence name="Sequence_3">
      <wait name="Wait_1" for="PT1M"/>
      <assign name="Assign_3">
        <copy>
```

```
IBM Websphere (also uses BPEL)
WebSphere Business Modeler (flowcharts are translated into BPEL)
Worklist in WebSphere
Management information in WebSphere
As shown ...

processes &
process models are
everywhere!!
Business process models versus information system models

“world”

business process

validates

models, analyzes

information system

controls

supports

implements, configures

analyzes, specifies

business process model

information system model

system model

data model

Employee
-empNo
-experience

Employee

Patient
-employeeID
-name
-address
-dateOfBirth
-gender

process model
Lifecycle of Business Information Systems

- **Requirements**
- **Runtime analysis**
- **Adjustment**
- **Implementation**
- **Production**
- **Deployment**
- **Distribution**
- **Configuration**
- **Execution**
- **Migration**
- **Design analysis**
- **(Re)design**

Flows:
- Requirements to (Re)design
- (Re)design to Design analysis
- Design analysis to Migration
- Migration to Execution
- Execution to Configuration
- Configuration to Deployment
- Deployment to Distribution
- Distribution to Implementation
- Implementation to Production
- Production to Adjustment
- Adjustment to Runtime analysis
- Runtime analysis to Requirements
Some trends

Trend 1: from data orientation to process orientation

Trend 2: from programming to assembling

Trend 3: from programming to configuration

Trend 4: toward redesign and organic growth
Preview

- Classical Petri net
- Extensions with
  - Color (data)
  - Time
  - Hierarchy
- Colored Petri Nets (CPN) language
- Analysis of processes
  - state-space analysis
  - structural methods
  - process mining
  - simulation
- Design patterns
- Other modeling techniques (UML, EPC, BPMN, ...)