# Lezione 14 – Model Transformations for BP Analysis and Execution

Ingegneria dei Processi Aziendali

Modulo 1 - Servizi Web

Unità didattica 1 – Protocolli Web

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# Business Process Management (BPM)

Collection of methods and techniques to design, analyze, execute and monitor business operations involving humans, software, information and physical artifacts using process models.



# OK, so what is a process model?

Collection of inter-dependent activities whose collective performance is intended to achieve a goal such as delivering a product or a service.

E,g. order-to-cash, procure-to-pay, issue-toresolution



### Process models serve many purposes...



# ... they have many faces



# ...and can be seen from many perspectives

**Control-flow** 

Data

#### Resource

### Operational



# Many in one, or one in many?

### "The thing can be many in one sense, but also can be one in another sense."

Imam Ghazali

**Revival of Religious Sciences** 

# Process Modelling: Dealing with Multiplicity

# **Multiple modelling languages (meta-models)** Multiple modelling viewpoints

- Control-flow view vs. data view
- Public views (protocols) vs. private views

### Multiple abstraction levels

- High-level: tasks, performance metrics...
- Low-level: data transformations, application bindings...

# **Process Modelling Notations**

- Business Process Modelling Notation (BPMN)
- Event-driven Process Chains (EPC)
- Business Process Execution Language (BPEL)
- State machines and variants (e.g. IBM Business State Machine, WWF)
- Petri nets (and variants, e.g. YAWL)

# Model transformations

### **BPMN-to-BPEL**

- Purpose: Transform models produced by analysts into models for developers (and vice-versa)
- Commonly supported in commercial tool, but in a limited manner

### **BPEL-to-Petri nets**

• For analysis & verification

### **BPMN-to-Petri nets**

 For analysis & verification (e.g. deadlockfreeness)

# **BPMN from 10 000 miles...**









Event

Task

Flow

Gateway

### **BPMN: A more detailed view**



# **Quick BPMN example**



# **BPEL from 10 000 miles**

- Basic activities: <assign>, <invoke>, <receive>
- Sequential flow: <sequence>, <while>, <switch>
- Block-structured parallel flow: <flow>
- Graph-oriented (parallel) flow: <*link*> \*\*
- Event-action rules: <onEvent> \*\*
- Other constructs not relevant to this talk...

**\*\*** Only partially supported by some tools

# A quick BPEL example

### <sequence> <invoke "check stock availability" .../> <switch (...) .../> <case "reject"> <invoke "order rejection" .../> </case> <otherwise> <sequence> <invoke "order acceptance" ... /> <flow> <invoke "invoicing" ... /> <invoke "ship goods" ... /> </flow> </sequence> </otherwise> </switch> </sequence> 15

### **BPMN-to-BPEL:** Some monsters!



instance task (D)

**Unstructured loop** 



**Unbounded multiple**instance tasks (C)



Livelock

# **BPMN-to-BPEL (from 10 000 miles)**

Repeat until reduction to a single node

- Identify a structured & quasi-structured SESE region
  → Fold into a BPEL structured activity
- Identify irreducible SESE regions without parallelism
  → Apply Goto→While transformations, repeat from 1
- 3. Identify acyclic fragments with concurrency
  → Fold into a BPEL activity with control links
- 4. Identify minimal unstructured components
  → BPEL event handlers

# **BPMN-BPEL: Structured Components**



### **BPMN-BPEL: Structured Components**



# **BPMN-BPEL: Structured Components**



# **Example: Only Structured Components**

#### Sequence-component



# **BPMN-to-BPEL: Acyclic component**

**BPMN** 

**BPEL** 

**Flow-component** 



Proposition: Every acyclic BPMN component with a single entry point and a single exit point that is 1-safe and sound can be mapped to a BPEL Flow with links

# Example Structured+Acyclic Components



### Minimizing the use of control links



# For the rest...

# Identify a minimal SESE region that is neither structured nor acyclic

### For each action in the component, retrieve:

- All actions that immediately precede it
- All actions that immediately follow it

# For each action, code the following behaviour using event-action rules:

- Wait for a suitable combination of predecessors to complete
- Perform action
- Notify completion to all successors

# BPEL-to-Petri net Application to Conformance Checking



# **From BPEL to WF-nets**



# **Petri net-based Conformance Checking**

### **Objectives:**

- quantitatively measure conformance
- locate deviations



# **Conformance Checking – Fitness**



# **Conformance Checking – Fitness**



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No. of InstancesLog Traces1207  
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ACGDHFA  
ACDHFA23  
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ACDHFA145  
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28 $ACHDFA$   
ACDHFA145  
23  
28 $ACHDFA$   
ACDHFA



$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$f = \frac{1}{2}(1 - \frac{0+}{(1207 \cdot 7)+}) + \frac{1}{2}(1 - \frac{0+}{(1207 \cdot 7)+})$$







 $\mid f = \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i} \right) + \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i} \right)$ 



$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 0 consumed tokens = 9remaining tokens = 0 produced tokens = 9

No. of Instances	Log Traces
1207	ABDEA
145	ACDGHFA
56	→ACGDHFA
23	ACHDFA
28	ACDHFA



$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$f = \frac{1}{2} \left(1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}\right) \\ + \frac{1}{2} \left(1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}\right)$$

missing tokens = 0 consumed tokens = 0remaining tokens = 0 produced tokens = 1





$$\left| f = \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i} \right) + \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i} \right) \right|$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 0 consumed tokens = 1remaining tokens = 0 produced tokens = 2

No. of Instances	Log Traces
1207	ABDEA
145	ACDGHFA
56	ACGDHFA
23	→ACHDFA
28	ACDHFA



$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens= 1consumed tokens= 2remaining tokens= 0produced tokens= 4





$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 1 consumed tokens = 3remaining tokens = 0 produced tokens = 5





$$\left| f = \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i} \right) + \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i} \right) \right|$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 1 consumed tokens = 4remaining tokens = 0 produced tokens = 6





$$\left| f = \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i} \right) + \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i} \right) \right|$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 1 consumed tokens = 6remaining tokens = 0 produced tokens = 7





$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$

$$\begin{split} f = & \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \\ & + \frac{1}{2} (1 - \frac{0 + 0 + 0 +}{(1207 \cdot 7) + ((145 + 56) \cdot 9) +}) \end{split}$$

missing tokens = 1 consumed tokens = 7remaining tokens = 0 produced tokens = 8





$$f = \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i}\right) + \frac{1}{2} \left(1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i}\right)$$



missing tokens	= 1	consumed tokens	= 8
remaining tokens	= 1	produced tokens	= 8

No. of Instances	Log Traces
1207	ABDEA
145	ACDGHFA
56	ACGDHFA
23	→ ACHDFA
28	ACDHFA



$$\left| f = \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i m_i}{\sum_{i=1}^{k} n_i c_i} \right) + \frac{1}{2} \left( 1 - \frac{\sum_{i=1}^{k} n_i r_i}{\sum_{i=1}^{k} n_i p_i} \right) \right|$$

$$\begin{split} f = & \frac{1}{2} \big( 1 - \frac{0 + 0 + 0 + (23 \cdot 1) + (28 \cdot 1)}{(1207 \cdot 7) + ((145 + 56) \cdot 9) + ((23 + 28) \cdot 8))} \big) \\ & + \frac{1}{2} \big( 1 - \frac{0 + 0 + 0 + (23 \cdot 1) + (28 \cdot 1)}{(1207 \cdot 7) + ((145 + 56) \cdot 9) + ((23 + 28) \cdot 8))} \big) \end{split}$$

missing tokens	= 1	consumed tokens	= 8
remaining tokens	= 1	produced tokens	= 8

No. of Instances	Log Traces
1207	ABDEA
145	ACDGHFA
56	ACGDHFA
23	ACHDFA
28	→ ACDHFA









# **Conformance Checking -Appropriateness**



100 % fitness but not sufficiently specific from **behavioral** point of view.

No. of Instances	Log Traces
1207	ABDEA
145	ACDGHFA
56	ACGDHFA
23	ACHDFA
28	ACDHFA

100 % fitness but not represented in **structurally** suitable way.

# **Ongoing work**

### **Reversible BPMN** $\leftrightarrow$ **BPEL transformation**

### **Two-way transformation: BPEL \leftrightarrow FSM**

- Application to automated service composition
- BPEL  $\rightarrow$  FSM not too difficult
- FSM  $\rightarrow$  BPEL more exciting, e.g.



