

# CS 4072 - Topics in CS Process Mining

Lecture # 16

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FAST - NUCES, CFD Campus

Dr. Rabia Maqsood

[rabia.maqsood@nu.edu.pk](mailto:rabia.maqsood@nu.edu.pk)

# Today's Topics

- ▶ Inductive Mining Algorithm
  - ▶ Process Trees

# Issues with other modeling techniques

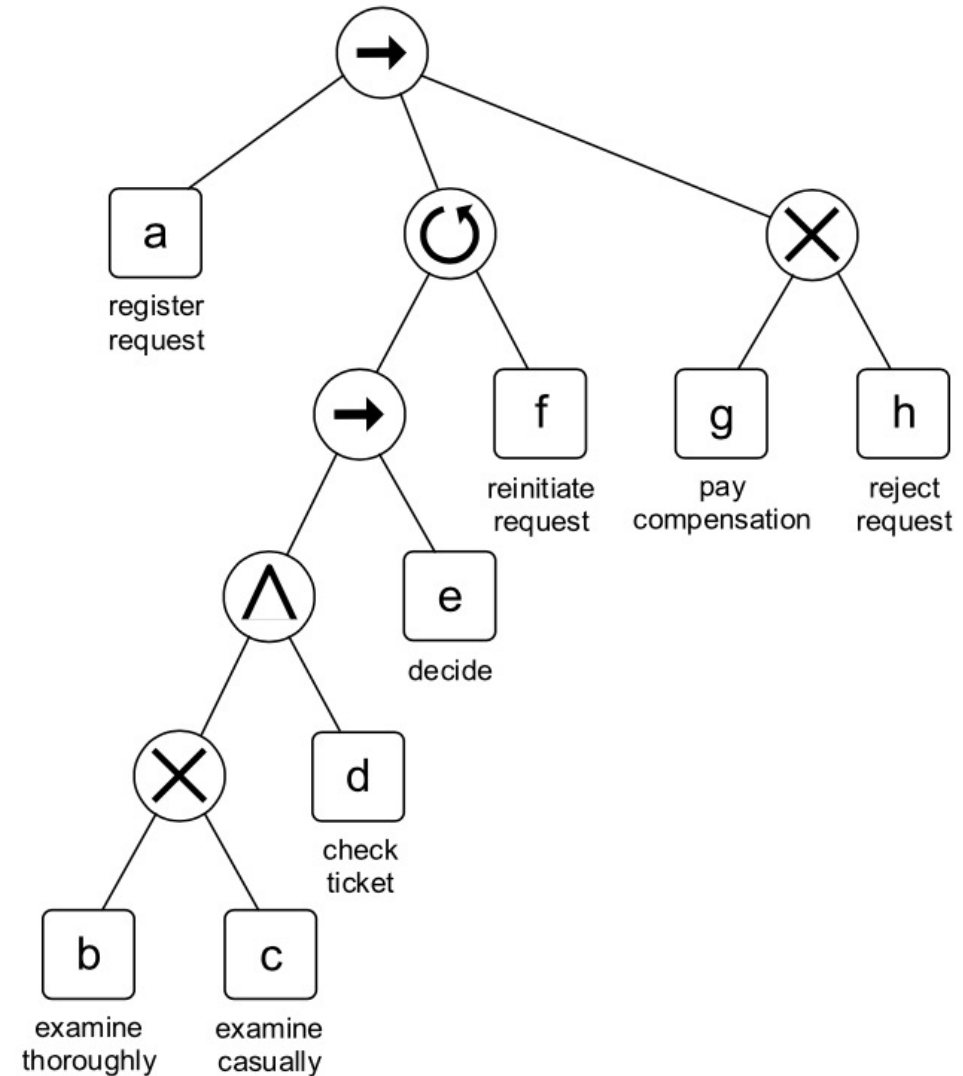
- ▶ Most of the process modeling techniques may suffer from deadlocks, livelocks, and other anomalies (e.g., Petri nets, WF-nets, BPMN, UML activity diagram).
- ▶ Models having undesirable properties *independent of the event log* are called *unsound*.
- ▶ Process discovery approaches using any of the graph-based process notations mentioned may produce unsound models.

# Issues with other modeling techniques

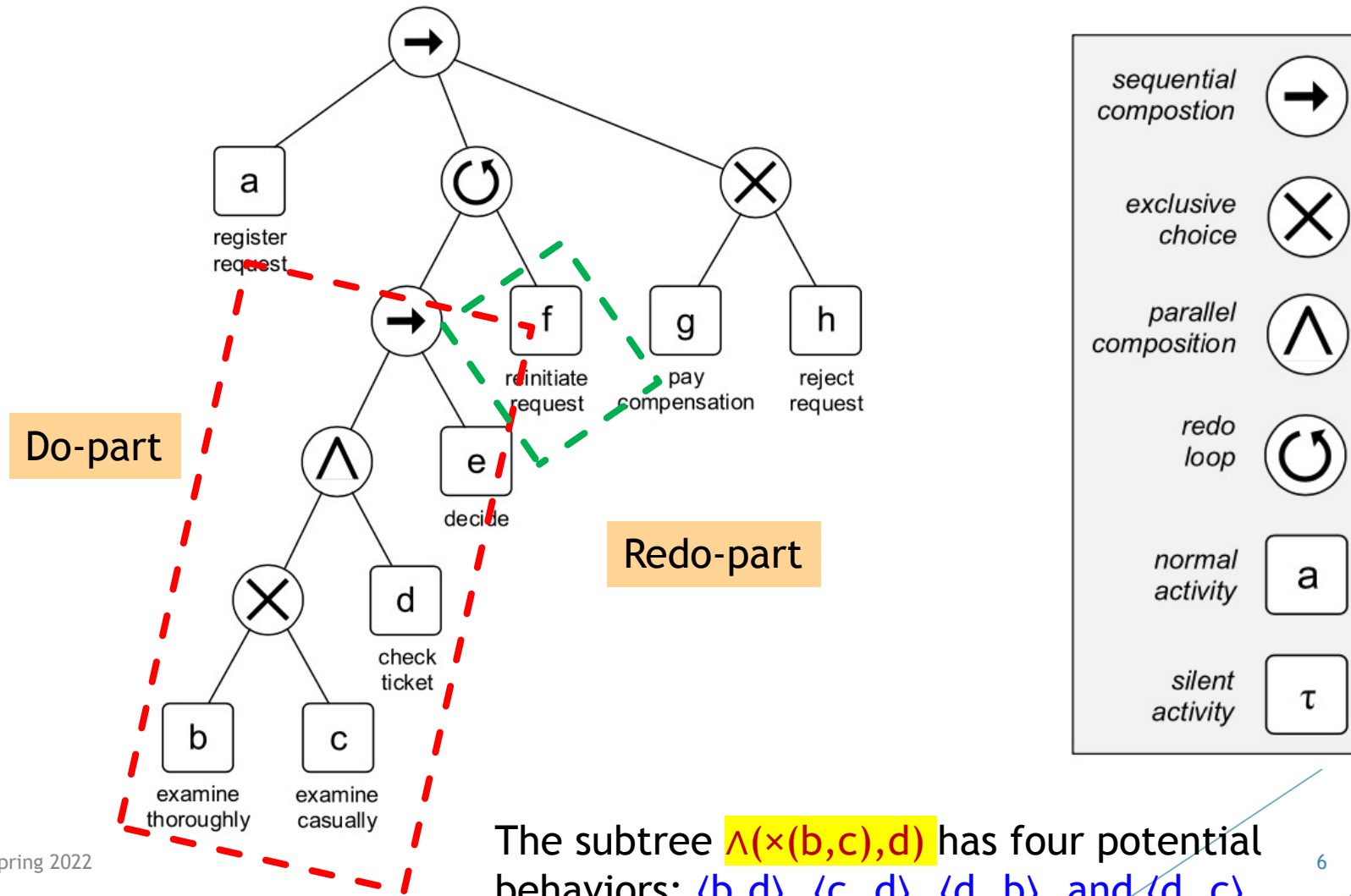
- ▶ C-nets address this problem by using more relaxed semantics.
- ▶ It is also possible to use *block-structured models* that are sound by construction e.g., **process trees**.

# Process Trees

- ▶ A process tree is a hierarchical process model where the (inner) nodes are **operators** such as *sequence and choice* and the **leaves** are **activities**.
- ▶ A range of *inductive process discovery* techniques exists for process trees, which benefit from the fact that the representation ensures soundness.



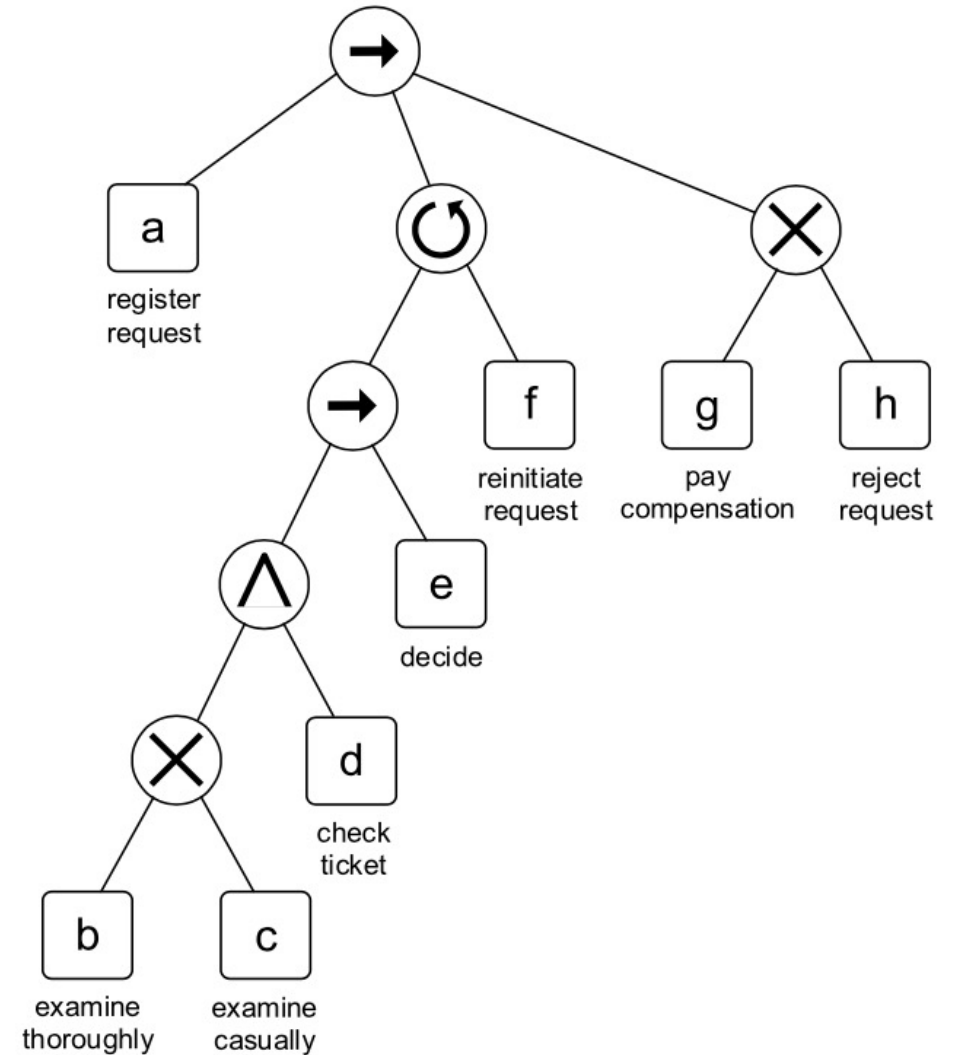
# Process Trees: operator & activity nodes



# Process Trees

- Can also be expressed by an expression:

$$\rightarrow (a, \circ(\rightarrow (\wedge(\times(b, c), d), e), f), \times(g, h))$$



# Process Trees: silent activity

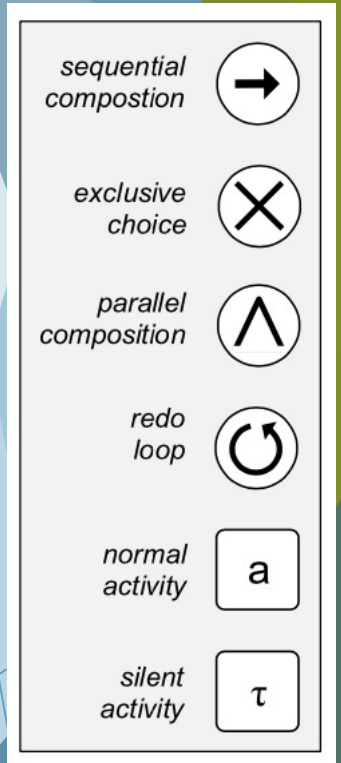
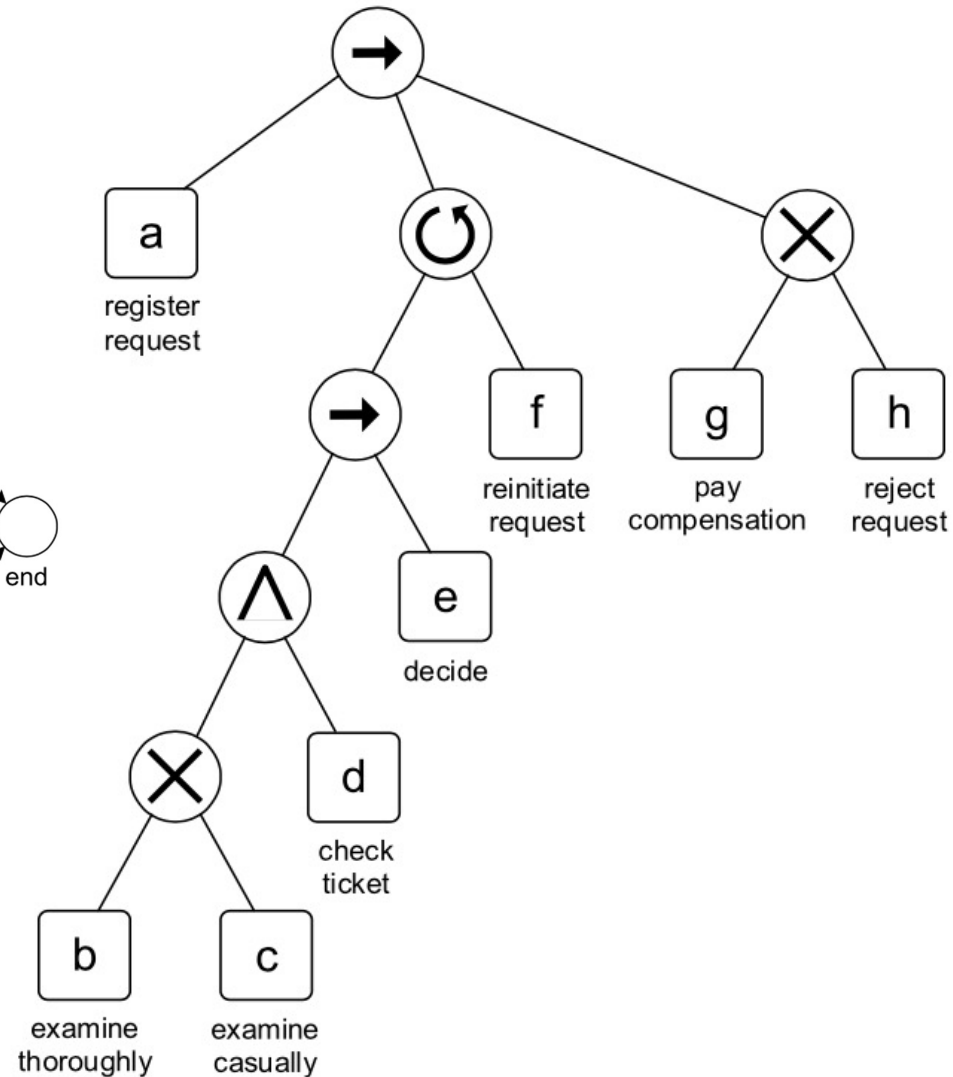
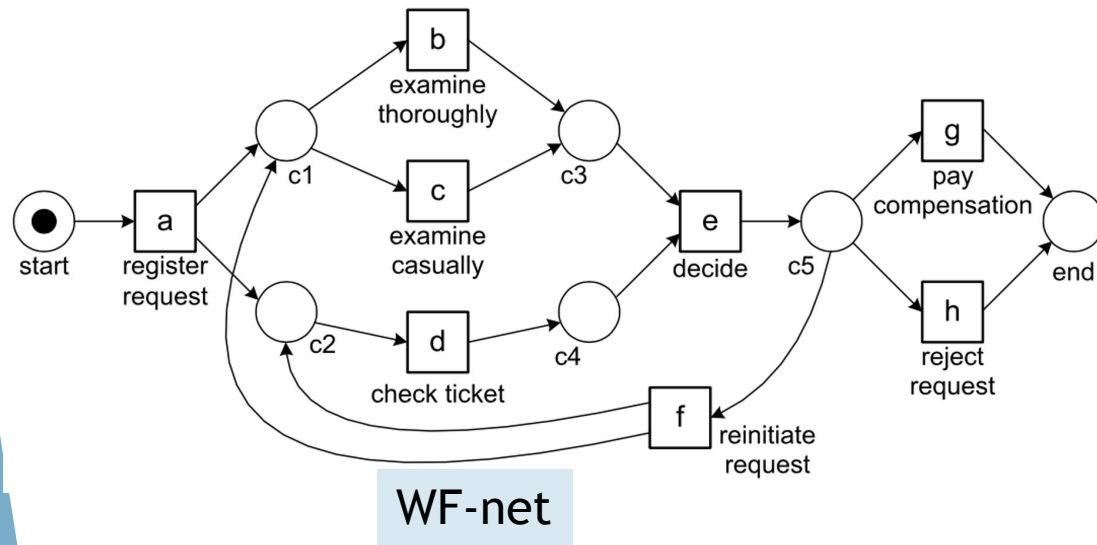
- ▶ A silent activity is denoted by  $\tau$  and cannot be observed.
  - ▶ Process tree  $\times(a, \tau)$  can be used to model an activity  $a$  that can be skipped.
  - ▶ Process tree  $\oslash(a, \tau)$  can be used to model the process that executes  $a$  at least once.
    - ▶ The “redo” part is silent, so the process can loop back without executing any activity.
  - ▶ Process tree  $\oslash(\tau, a)$  can be used to model the process that executes  $a$  any number of times.
    - ▶ The “do” part is now silent and activity  $a$  is in the “redo” part.



# Process Trees: notations

- ▶ The same activity may appear multiple times in the same process tree.
  - ▶ For example, process tree  $\rightarrow(a, a, a)$  models a sequence of three a activities.
- ▶ From a behavioral point of view,  $\rightarrow(a, a, a)$  and  $\wedge(a, a, a)$  are indistinguishable.
  - ▶ Both have one possible trace,  $\langle a, a, a \rangle$ .
- ▶ The smallest process tree is a tree consisting of just one activity.
  - ▶ In this case the root node is also a leaf node and there are no operator nodes.

# Process Trees: trace equivalence with WF-nets



# Process Trees

**Definition 3.13** (Process tree) Let  $A \subseteq \mathcal{A}$  be a finite set of activities with  $\tau \notin A$ .  $\oplus = \{\rightarrow, \times, \wedge, \circ\}$  is the set of *process tree operators*.

- If  $a \in A \cup \{\tau\}$ , then  $Q = a$  is a process tree,
- If  $n \geq 1$ ,  $Q_1, Q_2, \dots, Q_n$  are process trees, and  $\oplus \in \{\rightarrow, \times, \wedge\}$ , then  $Q = \oplus(Q_1, Q_2, \dots, Q_n)$  is a process tree, and
- If  $n \geq 2$  and  $Q_1, Q_2, \dots, Q_n$  are process trees, then  $Q = \circ(Q_1, Q_2, \dots, Q_n)$  is a process tree.

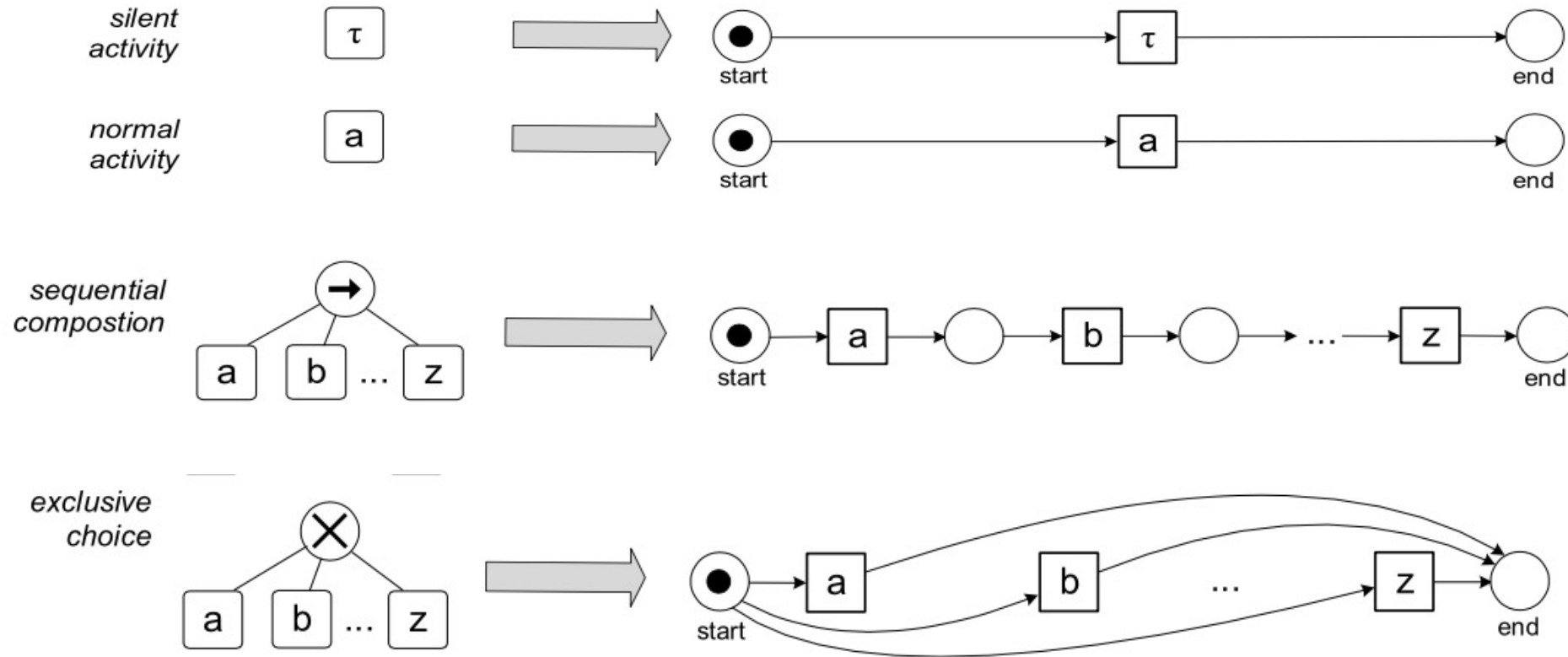
$\mathcal{Q}_A$  is the set of *all process trees* over  $A$ .

# Process Trees: loop operator

The redo loop operator  $\circ$  has at least two children.  
First child is the “do” part and the other children are “redo” parts.

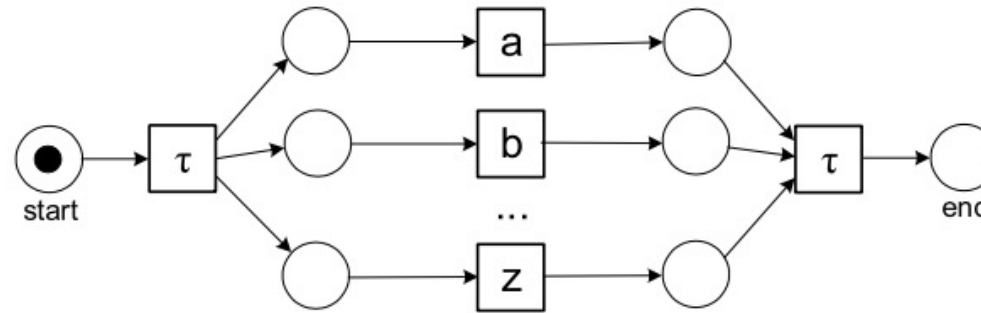
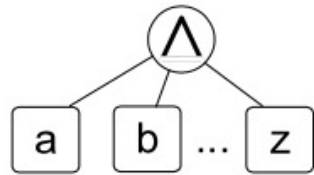
- ▶ Process tree  $\circ(a,b,c)$  allows the following traces:  
 $\{\langle a \rangle, \langle a,b,a \rangle, \langle a,c,a \rangle, \langle a,b,a,b,a \rangle, \langle a,c,a,c,a \rangle, \langle a,c,a,b,a \rangle, \langle a, b, a, c, a \rangle, \dots\}$ 
  - ▶ Activity a is executed at least once and the process always starts and ends with a.
  - ▶ The “do” part alternates with the “redo” parts b or c.
  - ▶ When looping back either b or c is executed.
- ▶ The redo loop operator  $\circ$  is often used in conjunction with silent activity  $\tau$ .
- ▶ For example  $\circ(\tau,a,b,c,\dots,z)$  allows for any “word” involving activities a,b,c,...,z.
  - ▶ Example traces are  $\langle \rangle$ ,  $\langle a,b,b,a \rangle$ , and  $\langle w,o,r,d \rangle$ .

# Mapping Process Trees onto WF-nets

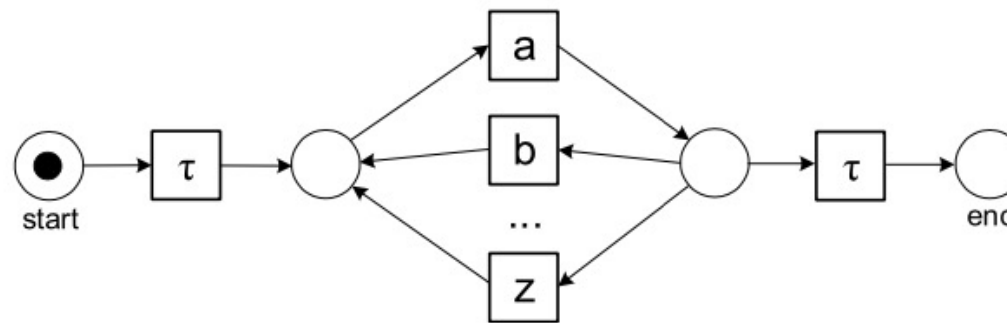
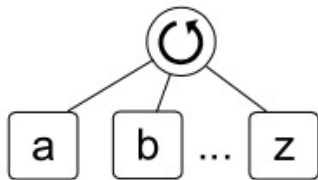


# Mapping Process Trees onto WF-nets

*parallel composition*



*redo loop*



# Reading Material

- ▶ Chapter 3: Aalst