Methods for the specification and verification of business processes

MPB (6 cfu, 295AA)

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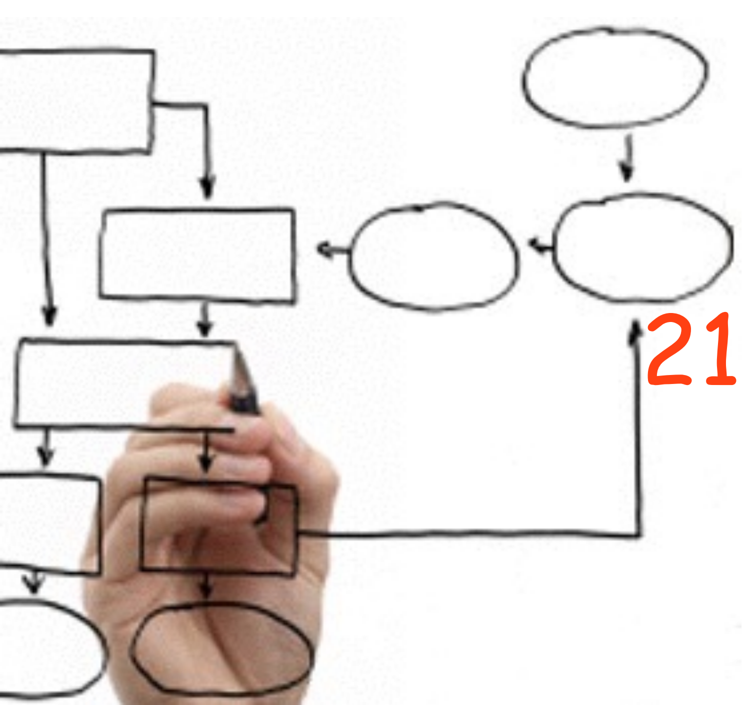
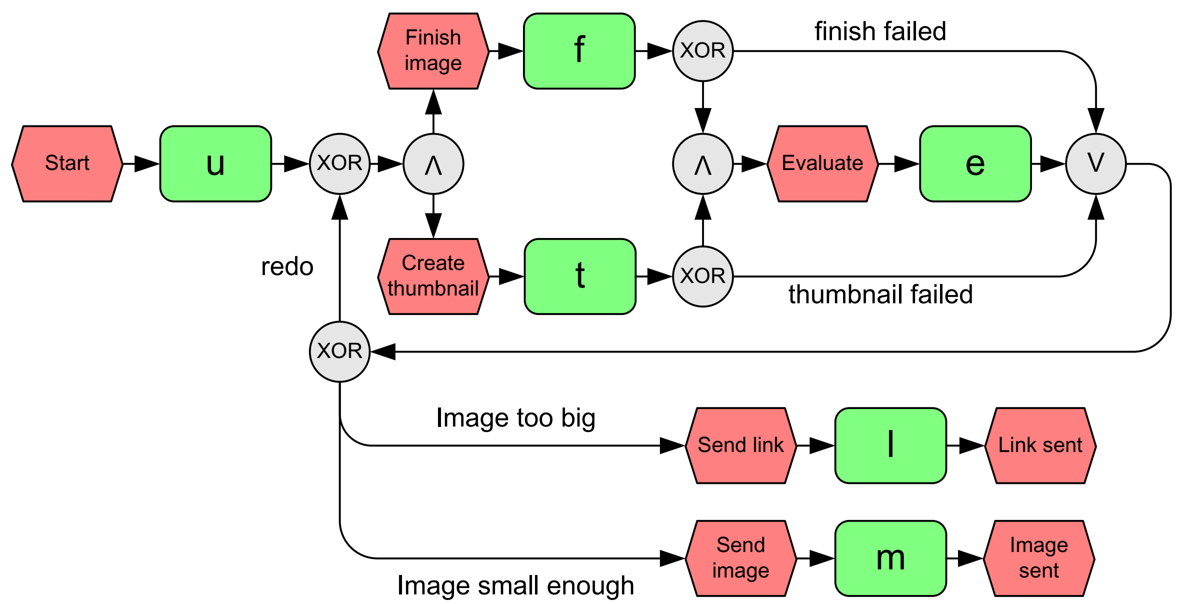
http://www.di.unipi.it/~bruni



21 - Event-driven process chains

Object



We overview EPC and the main challenges that arise when analysing them with Petri nets

Ch.4.3, 6 of Business Process Management: Concepts, Languages, Architectures

Event-driven Process Chain

An **Event-driven Process Chain** (EPC)
is a particular type of flow-chart
that can be used for configuring an
Enterprise Resource Planning (ERP) implementation

Supported by many tools (e.g. SAP R/3)

EPC Markup Language available (EPML)
as interchange format

EPC overview

Rather informal notation
simple and easy-to-understand

EPC focus is on
representing domain concepts and processes
(not their formal aspects and technical realization)

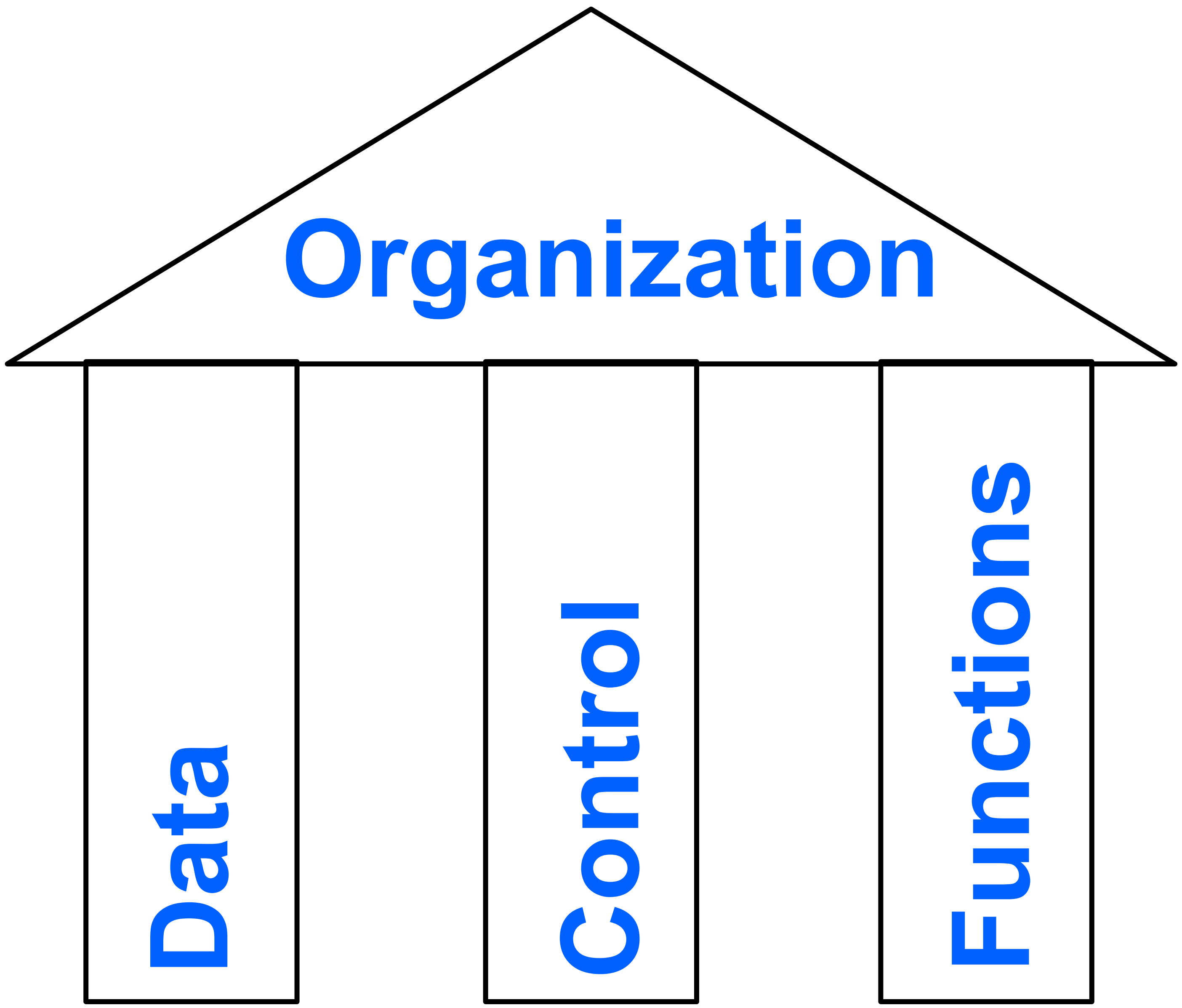
It can be used to drive the
modelling, analysis and redesign of business process

EPC origin

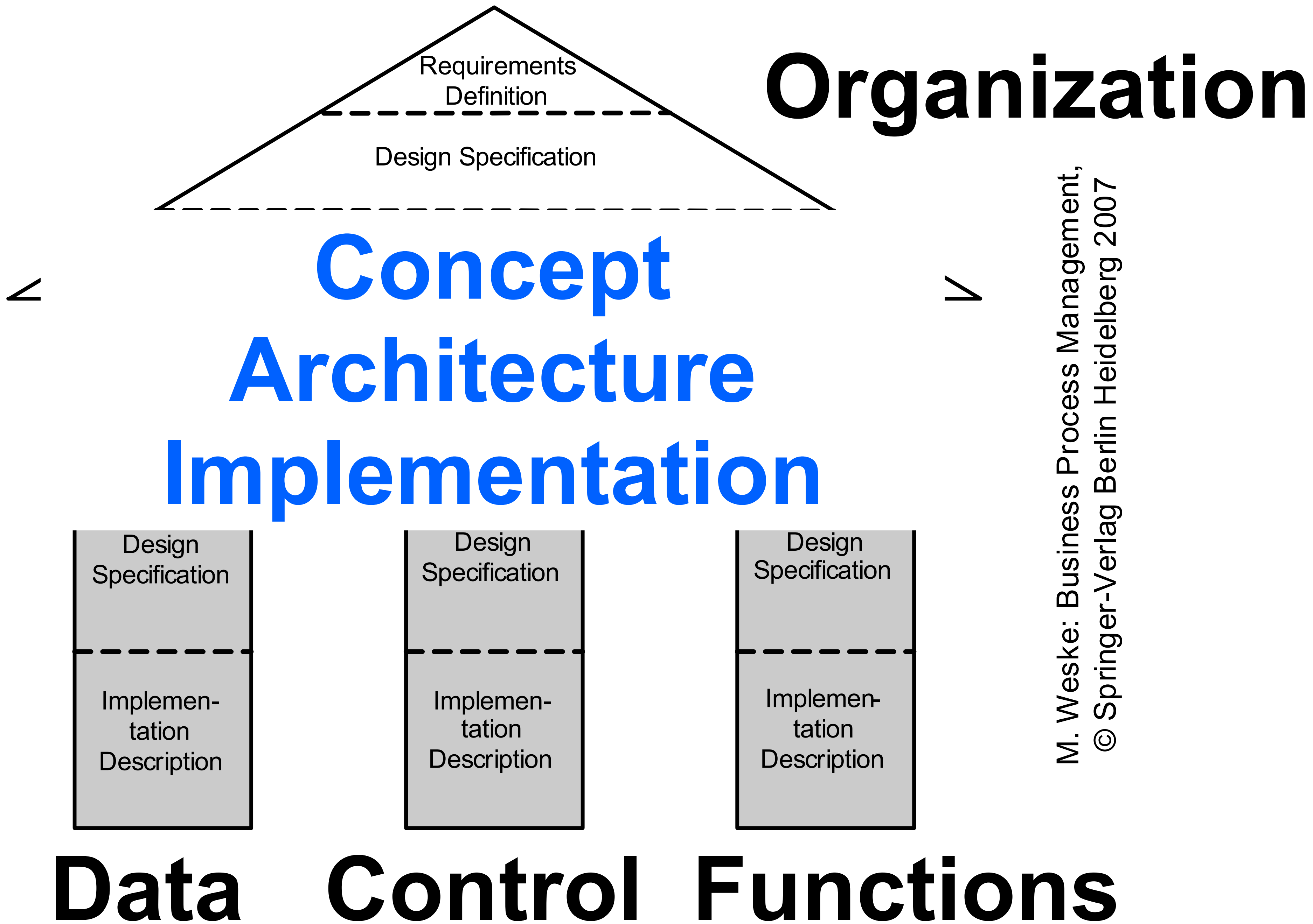
EPC method was originally developed by Wilhelm-August Scheer (early 1990’s)

Part of a holistic modelling approach called ARIS framework
(Architecture of Integrated Information Systems)

ARIS house (1999): three pillars and a roof...



...and three levels of abstraction each



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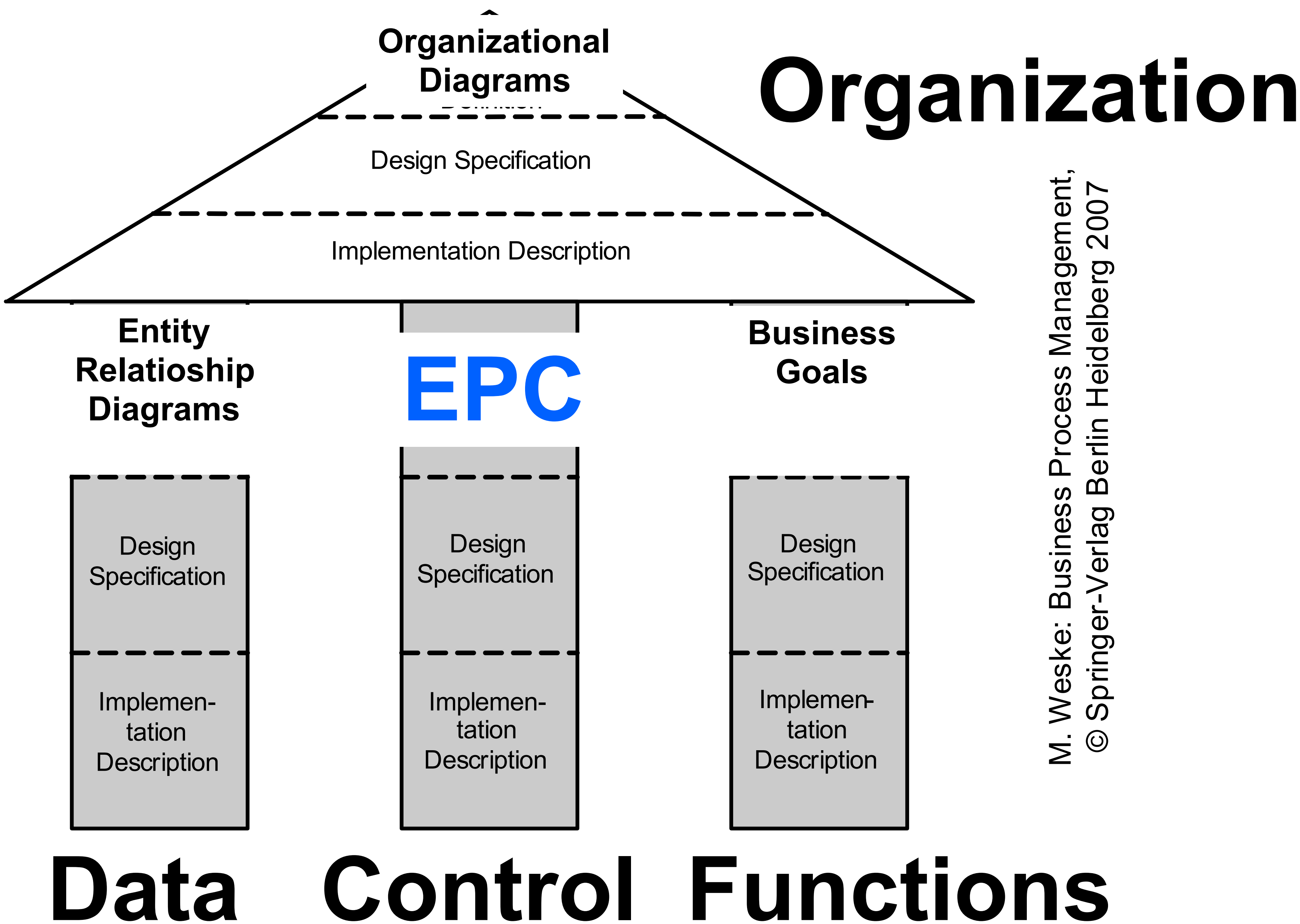


EPC informally

An EPC is an “ordered” graph
of **events** and **functions**

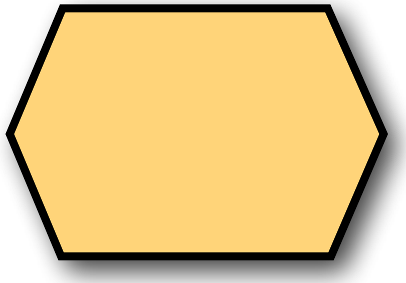
It provides various **connectors** that allow
alternative and parallel execution of processes

The flow is specified by logical operators
AND, XOR, OR

Events

Any EPC diagram must
start with **event(s)**
and end with **event(s)**

Passive elements used to describe
under which circumstances a process (or a function) works
or which state a process (or a function) results in
(like pre- / post-conditions)



Graphical representation: hexagons

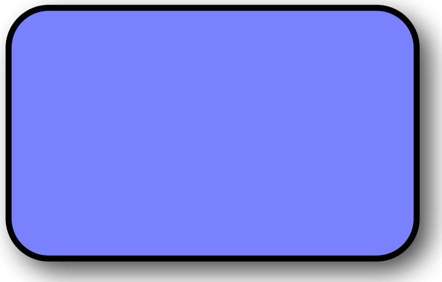
Functions

Any EPC diagram may involve several **functions**

Active elements used to describe the tasks or activities of a business process

Functions can be refined to other EPC

Graphical representation: rounded rectangles



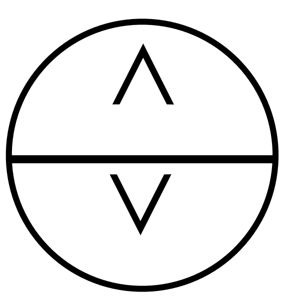
Logical connectors

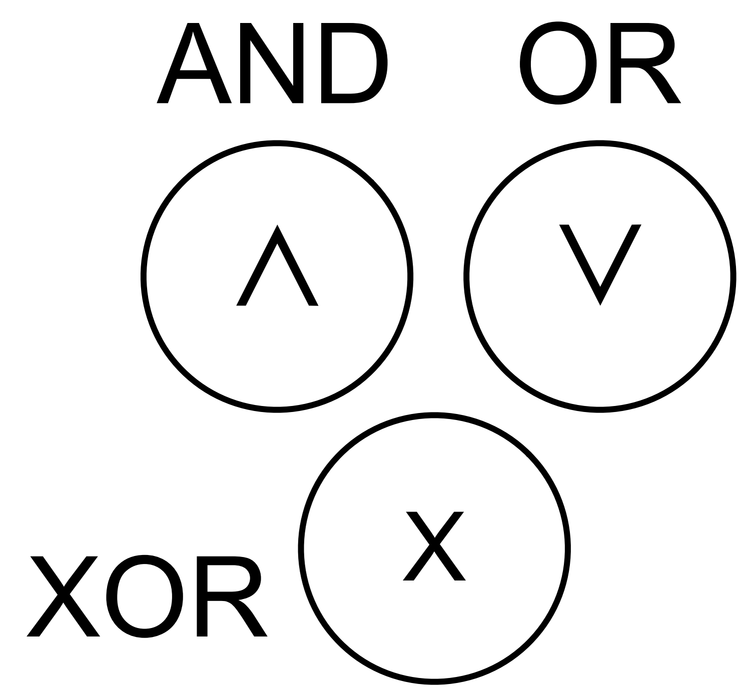
Any EPC diagram may involve
several **connectors**

Elements used to describe
the logical relationships between elements in the diagram

Branch, merge, fork, join

Graphical representation:
circles (or also octagons)





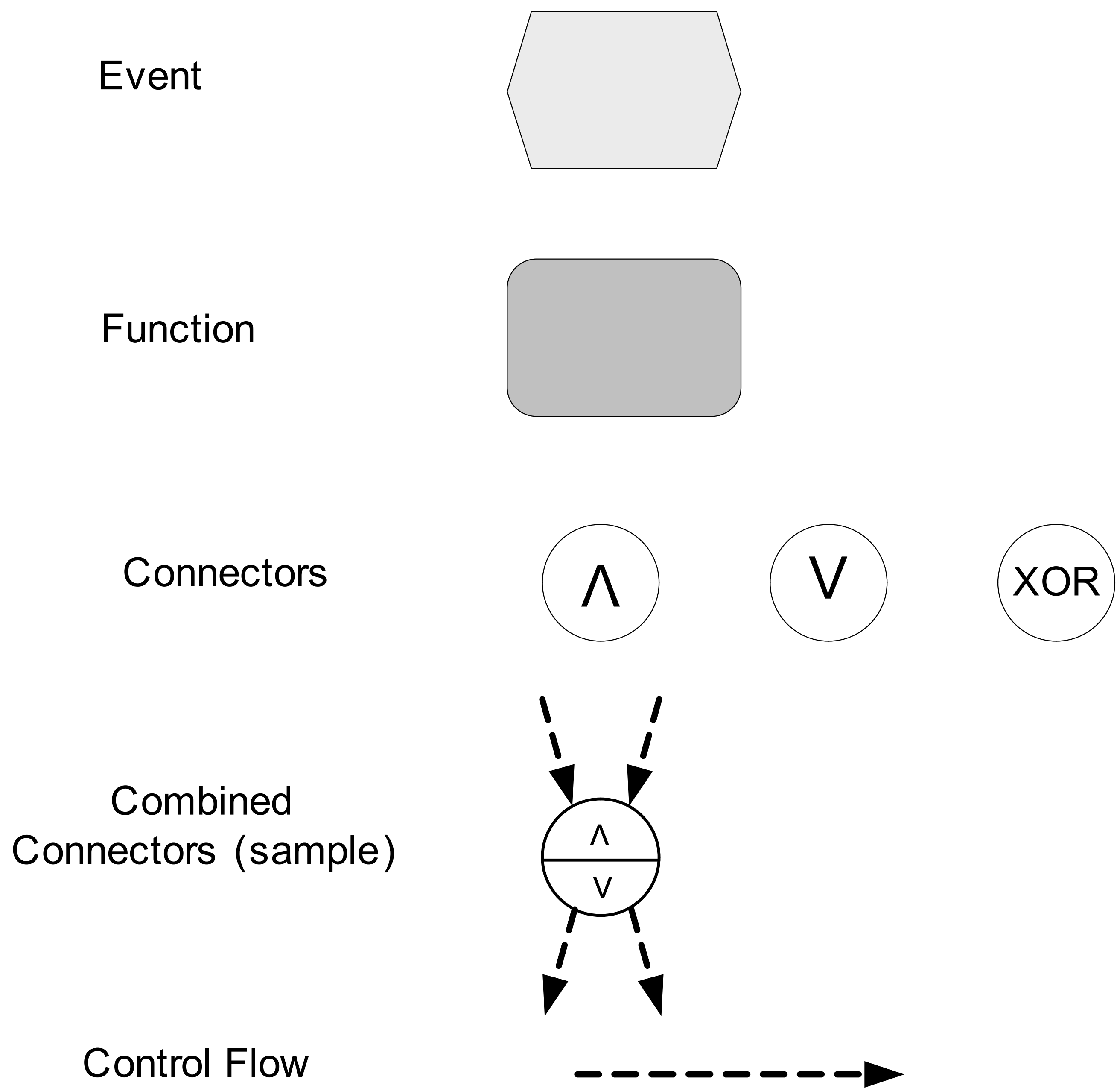
Control flow

Any EPC diagram may involve
several **control flow connections**

Control flow is used to connect
events with functions and connectors
by expressing causal dependencies

Graphical representation:
dashed arrows

EPC ingredients at a glance



EPC diagrams

EPC elements can be combined in a fairly free manner
(possibly including cycles)

There must be at least one start event and one end event
Events have at most one incoming and one outgoing arc
Events have at least one incident arc

Functions have exactly one incoming and one outgoing arc

The graph is weakly connected (no isolated nodes)

Connectors have either one incoming arc and multiple outgoing arcs
or viceversa (multiple incoming arcs and one outgoing arc)

EPC ingredients: Diagrams

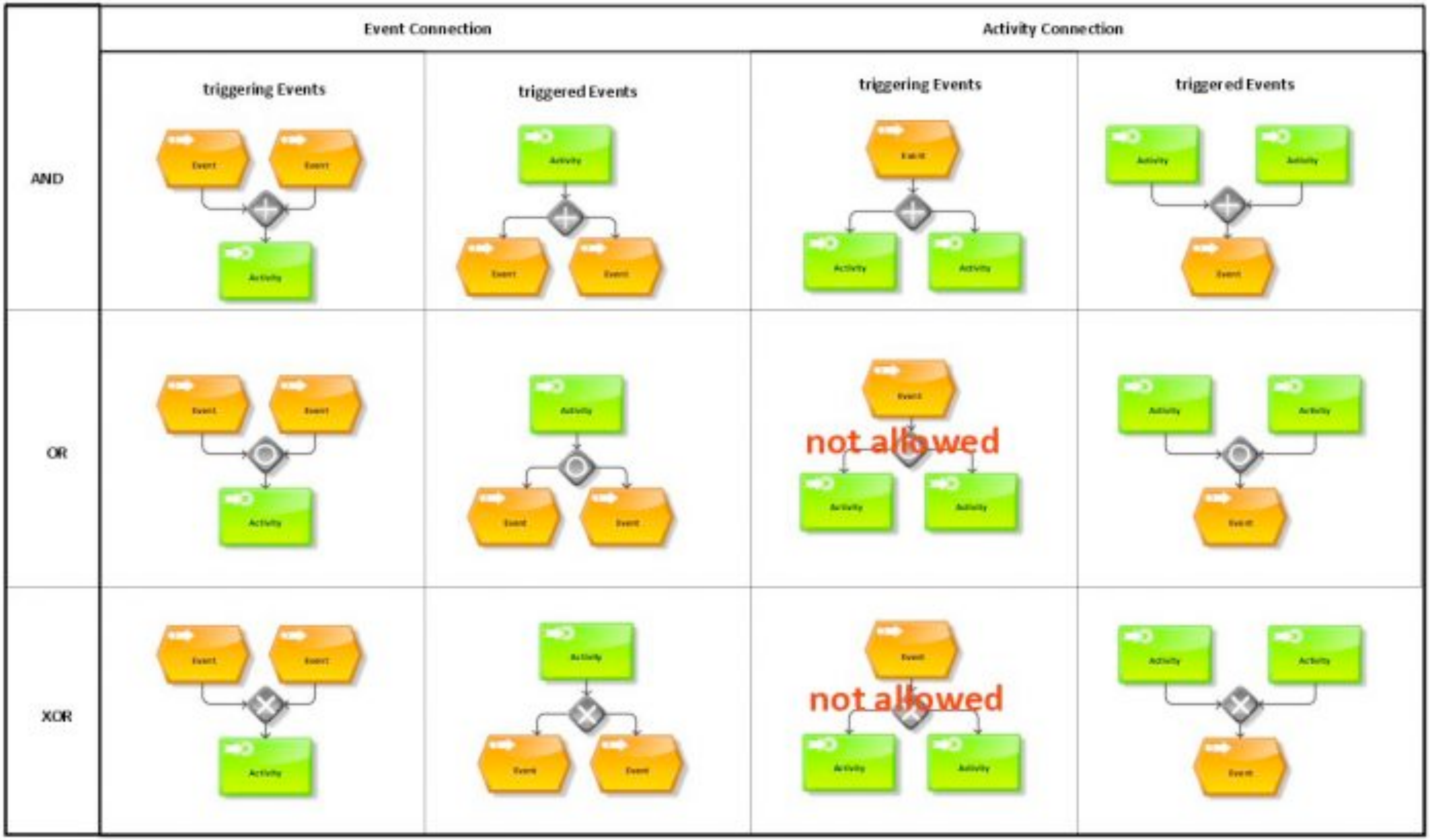
Other constraints are sometimes imposed

Unique start / end event

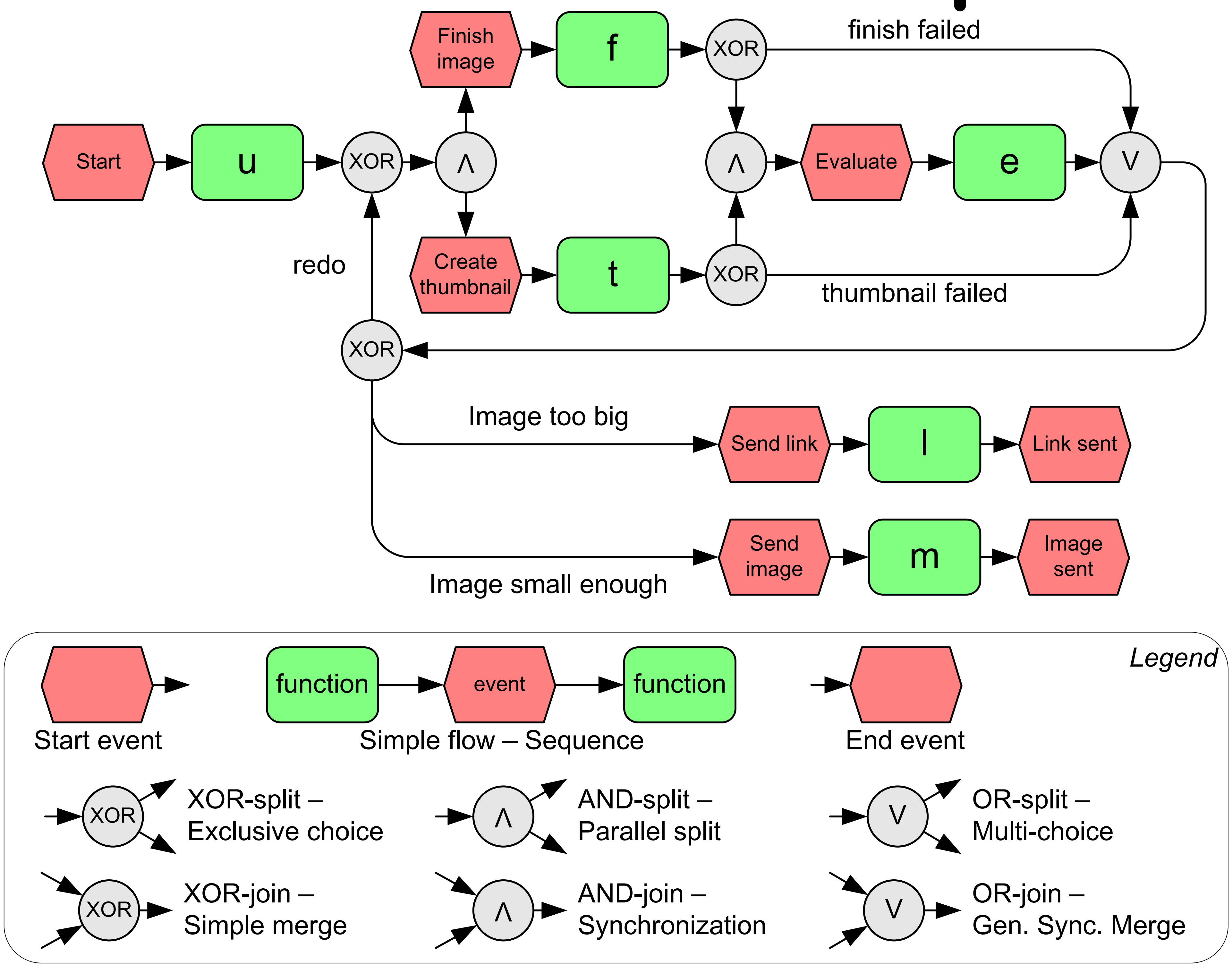
No arc between two events
No arc between two functions

No event is followed by a decision node
(i.e. (X)OR-split)

EPC allowed connections

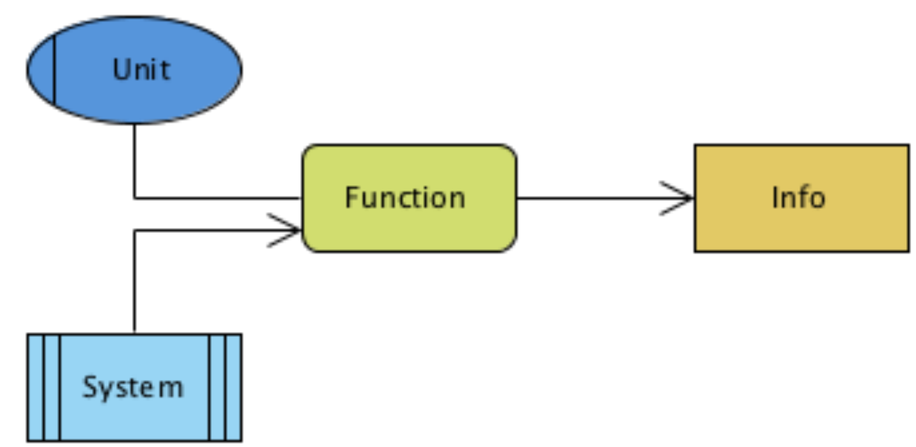


EPC an example



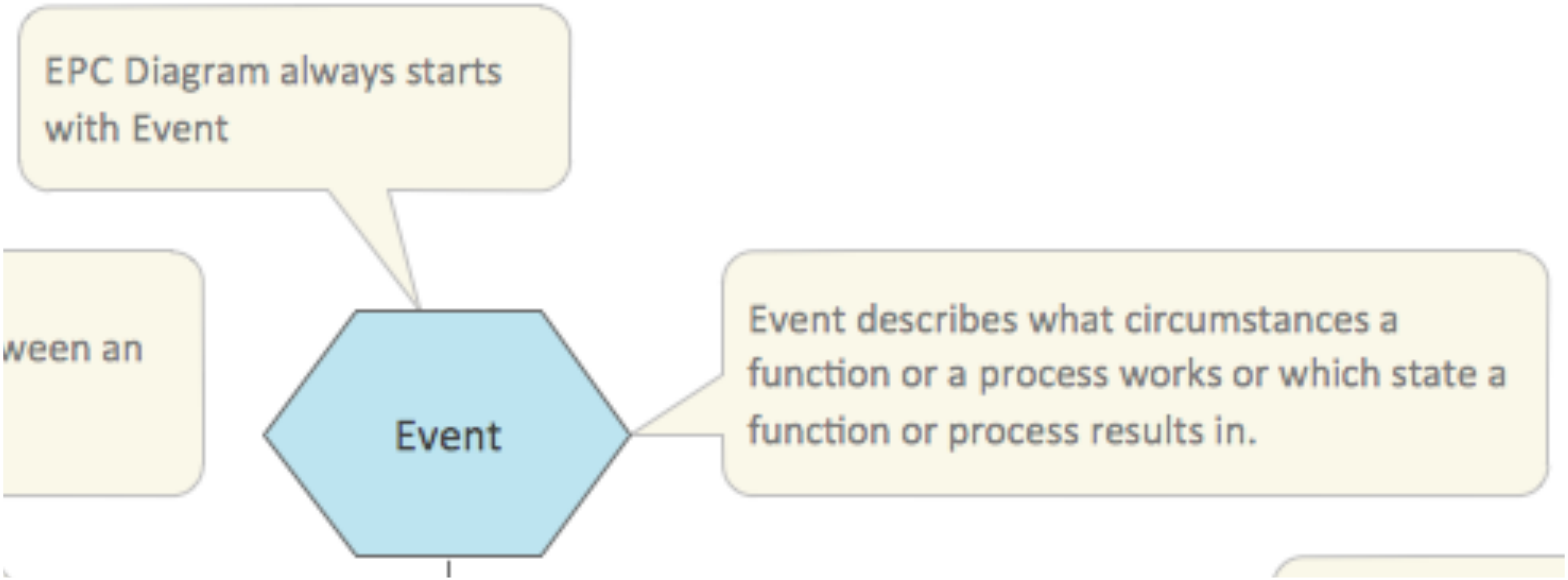
Other annotations for functions

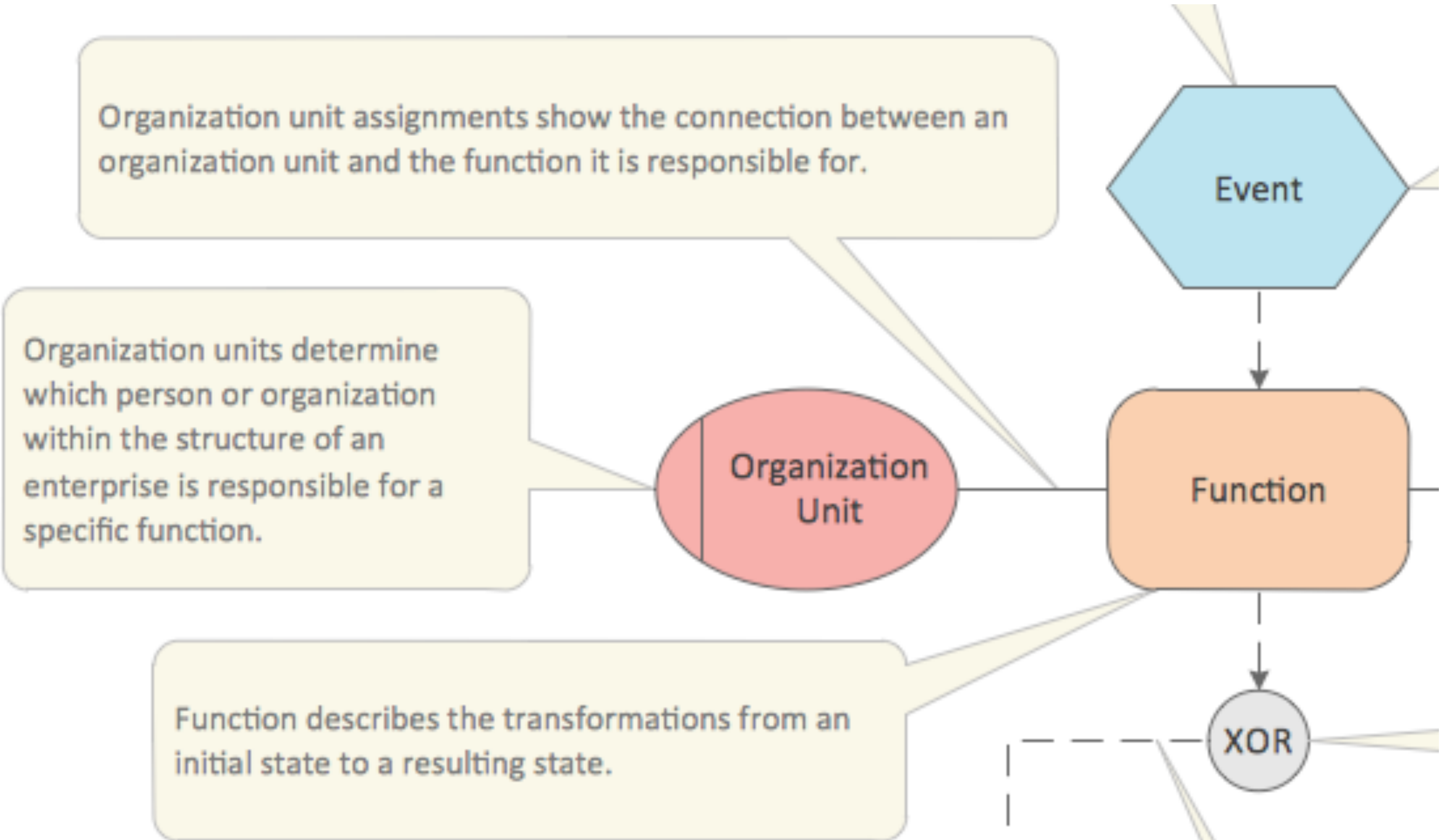
Information, material, resource object:
represents objects in the real world
e.g. input data or output data for a function
(rectangles linked to function boxes)

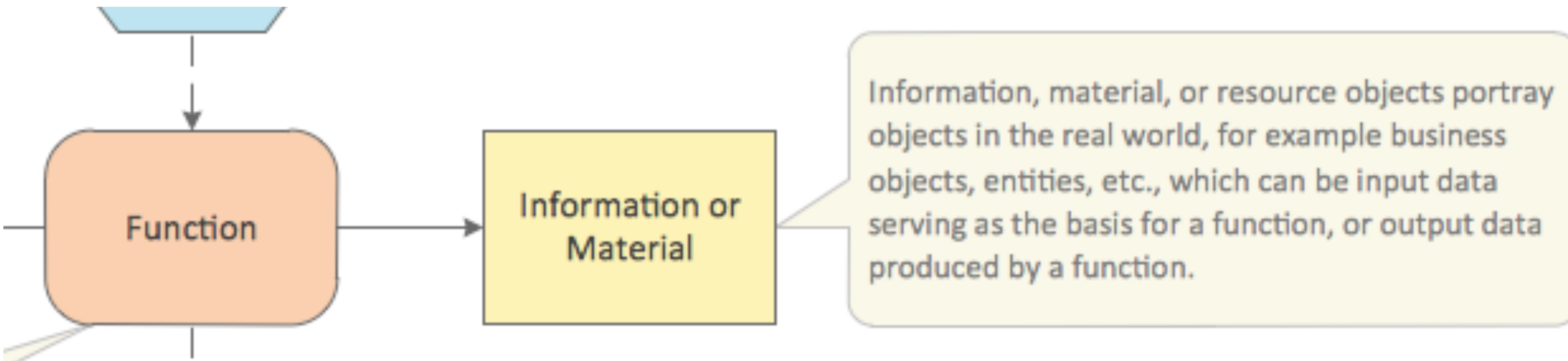


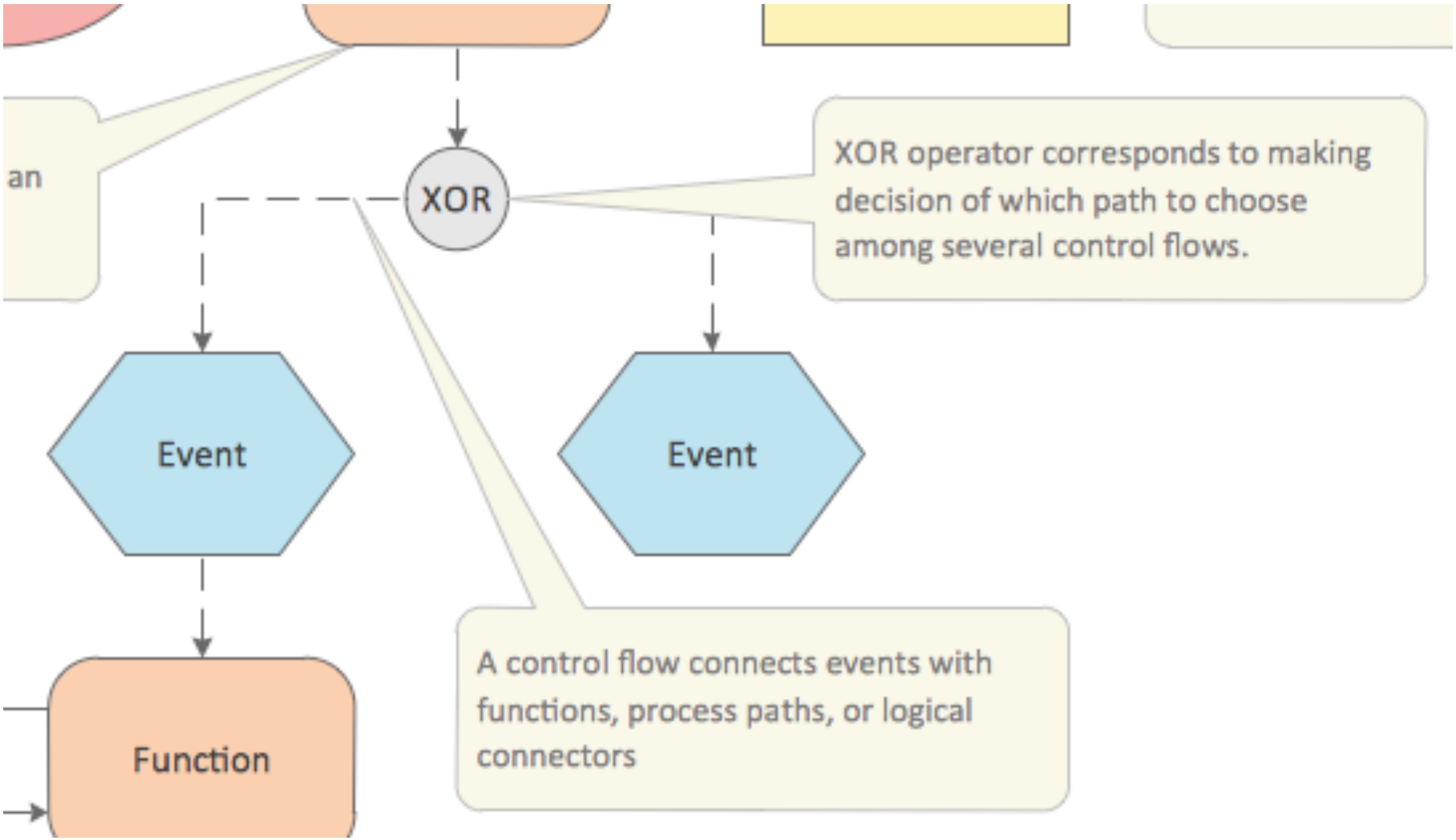
Organization unit:
determines the person or organization responsible for a specific function
(ellipses with a vertical line)

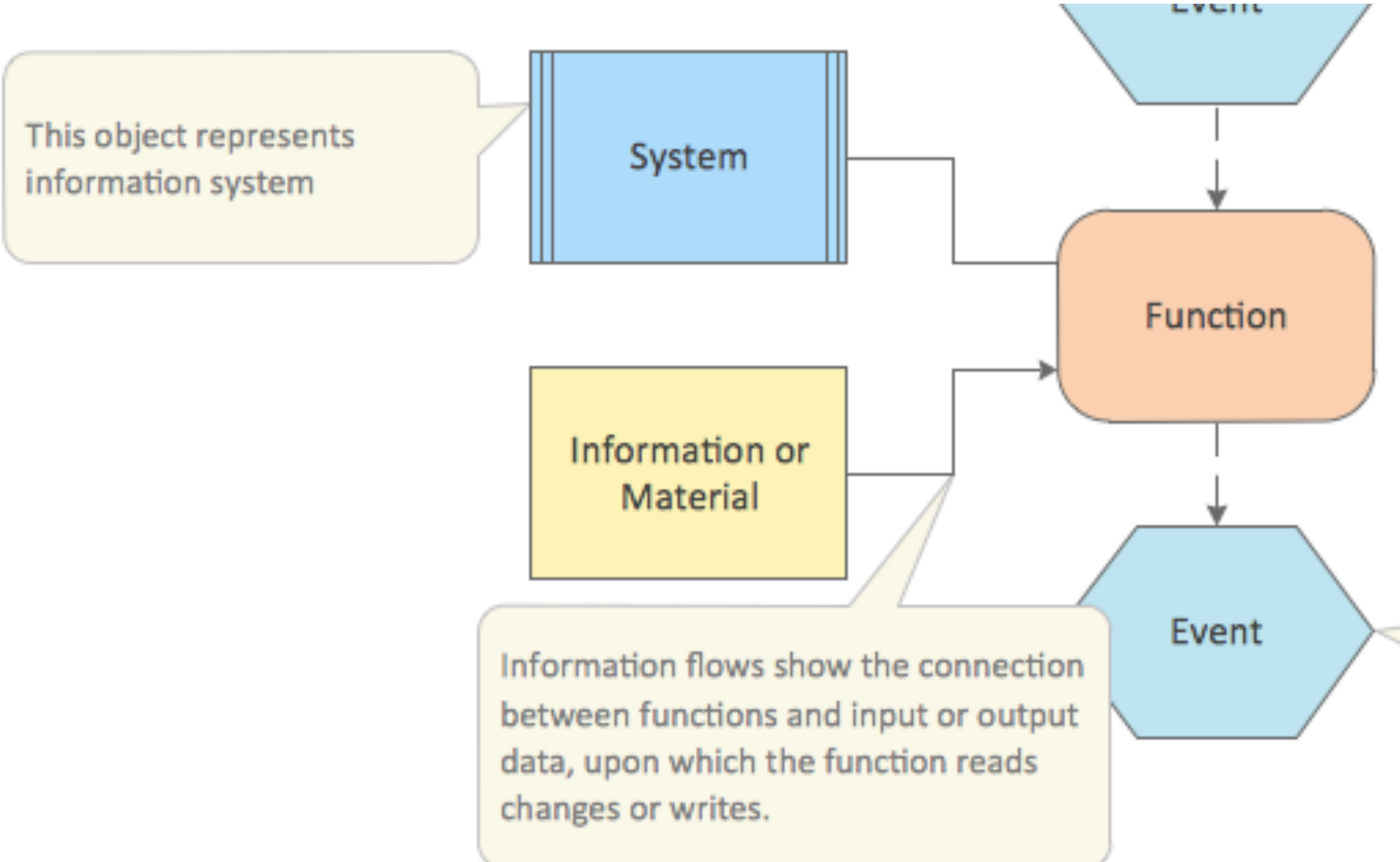
Supporting system: technical support
(rectangles with vertical lines on its sides)

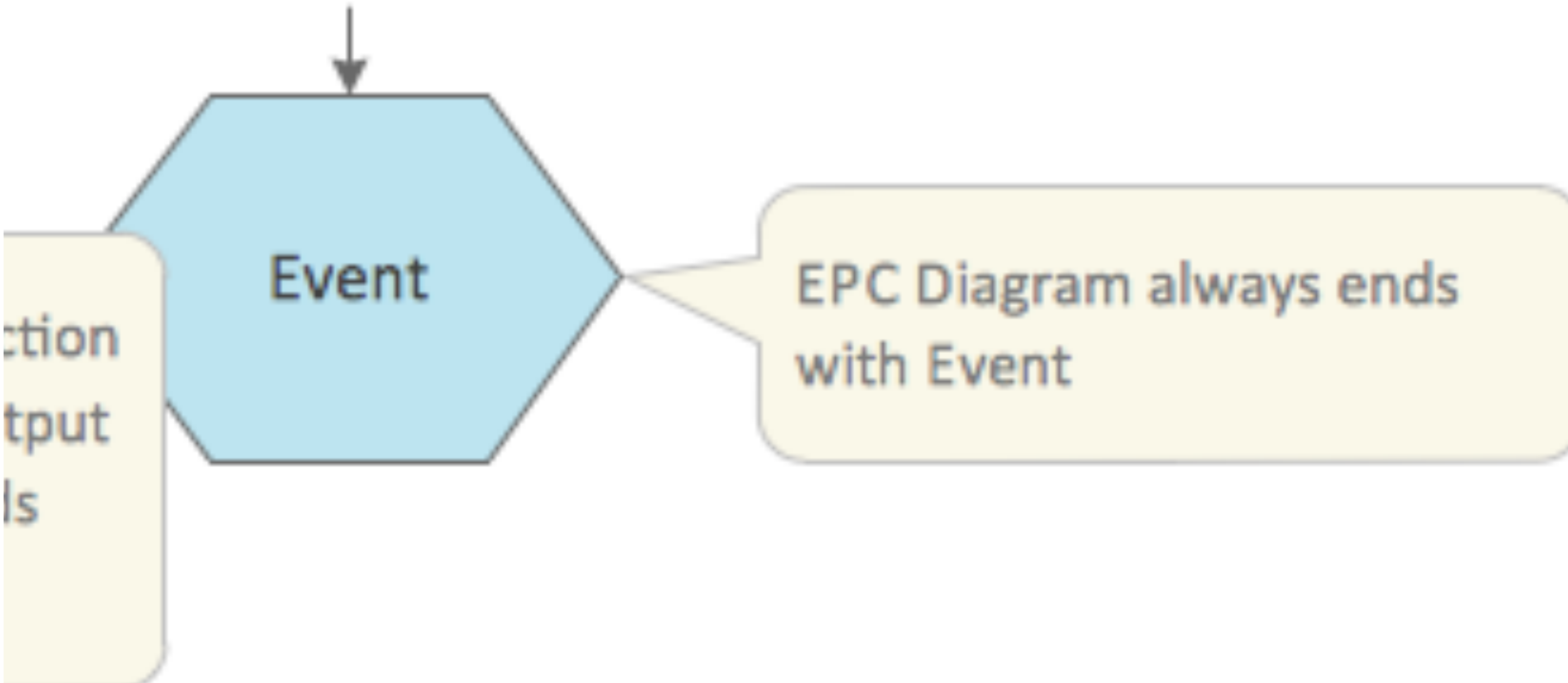

EPC Diagram always starts with Event
ween an
Event
Event describes what circumstances a function or a process works or which state a function or process results in.


Organization unit assignments show the connection between an organization unit and the function it is responsible for.
Event
Organization units determine which person or organization within the structure of an enterprise is responsible for a specific function.
Organization Unit
Function
Function describes the transformations from an initial state to a resulting state.
XOR


Function
Information or Material
Information, material, or resource objects portray objects in the real world, for example business objects, entities, etc., which can be input data serving as the basis for a function, or output data produced by a function.


an
XOR
XOR operator corresponds to making decision of which path to choose among several control flows.
Event
Event
A control flow connects events with functions, process paths, or logical connectors
Function


Event
This object represents information system
System
Function
Information or Material
Event
Information flows show the connection between functions and input or output data, upon which the function reads changes or writes.


Event
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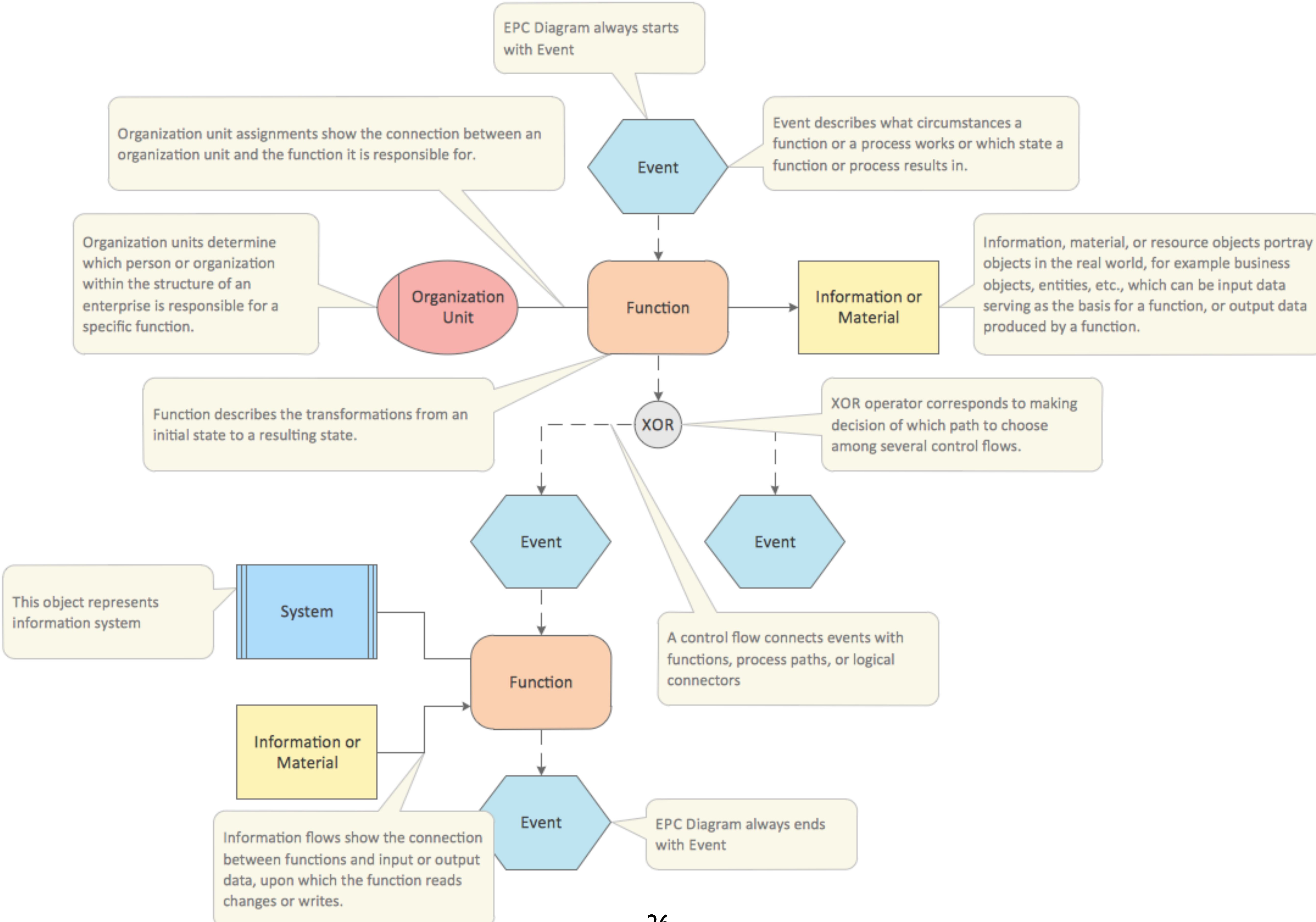
tput
ds
EPC Diagram always ends with Event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EPC Diagram always ends with Event
Information flows show the connection between functions and input or output data, upon which the function reads changes or writes.

EPC intuitive semantics

A process starts when some initial event(s) occurs

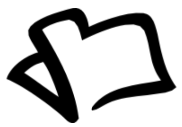
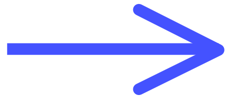
The activities are executed according to the constraints in the diagram

When the process is finished, only final events have not been dealt with

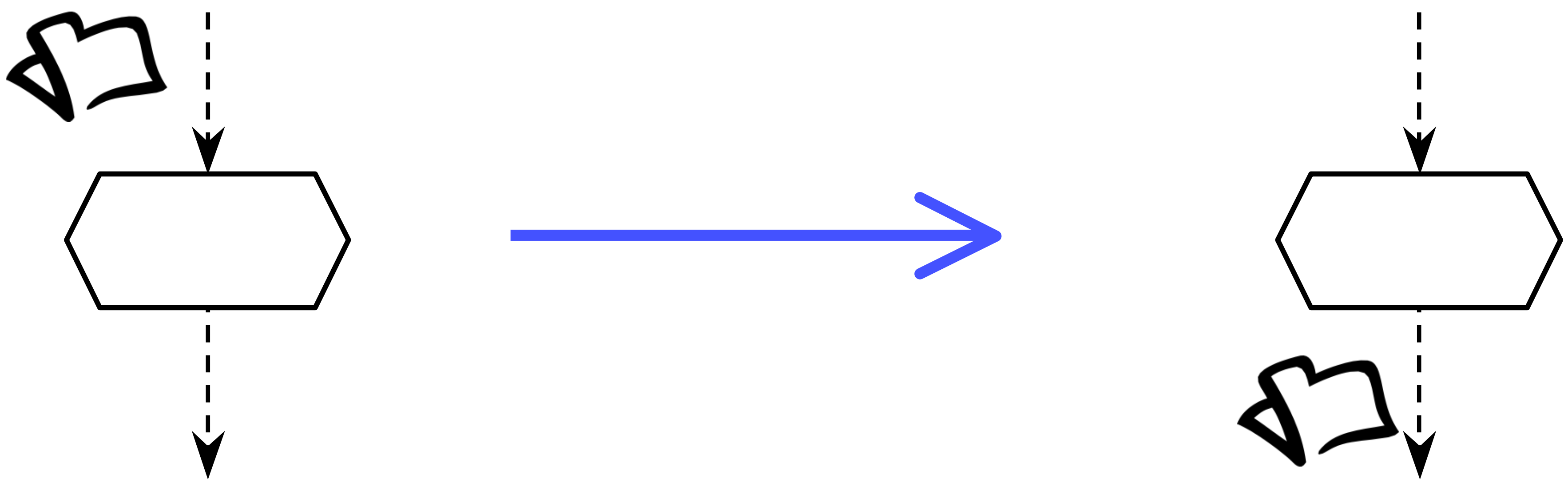
If this is always the case, then the EPC is “correct”

Folder-passing semantics

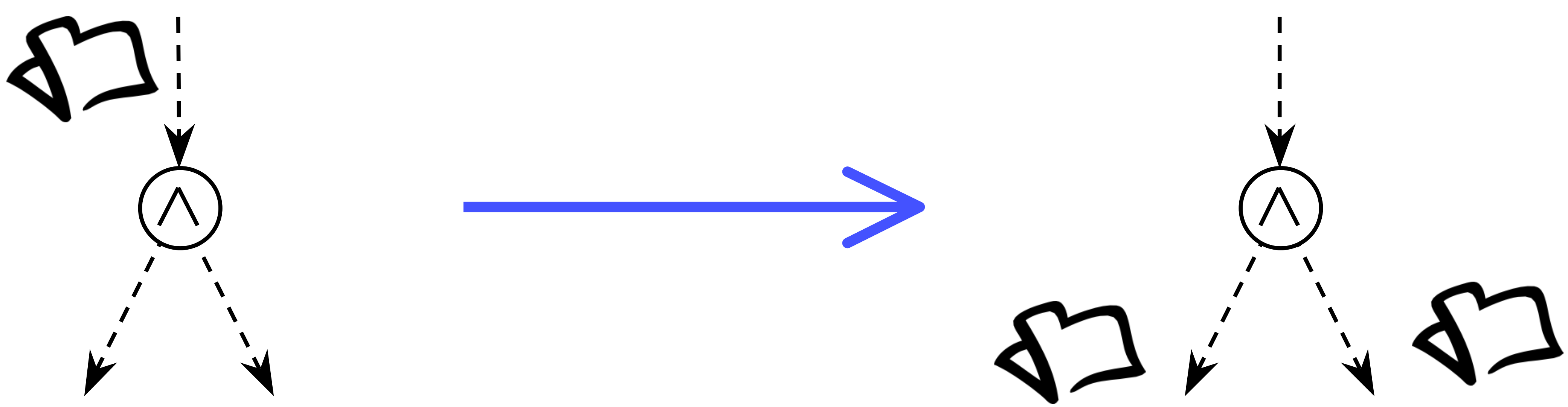
Semantics

- State: Process folders 
- Transition relation:
  Propagation of process folders 

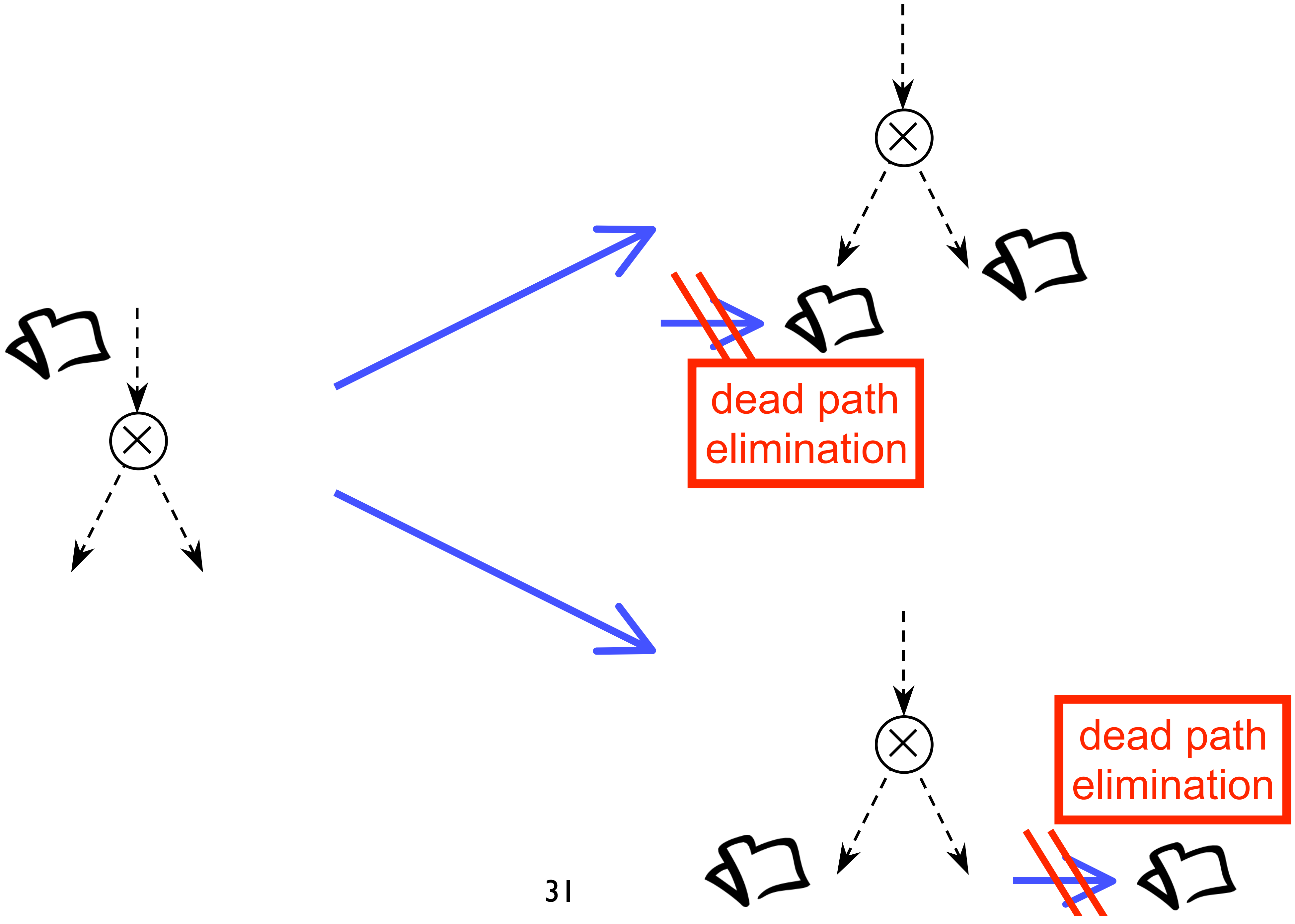
Folder-passing semantics: events



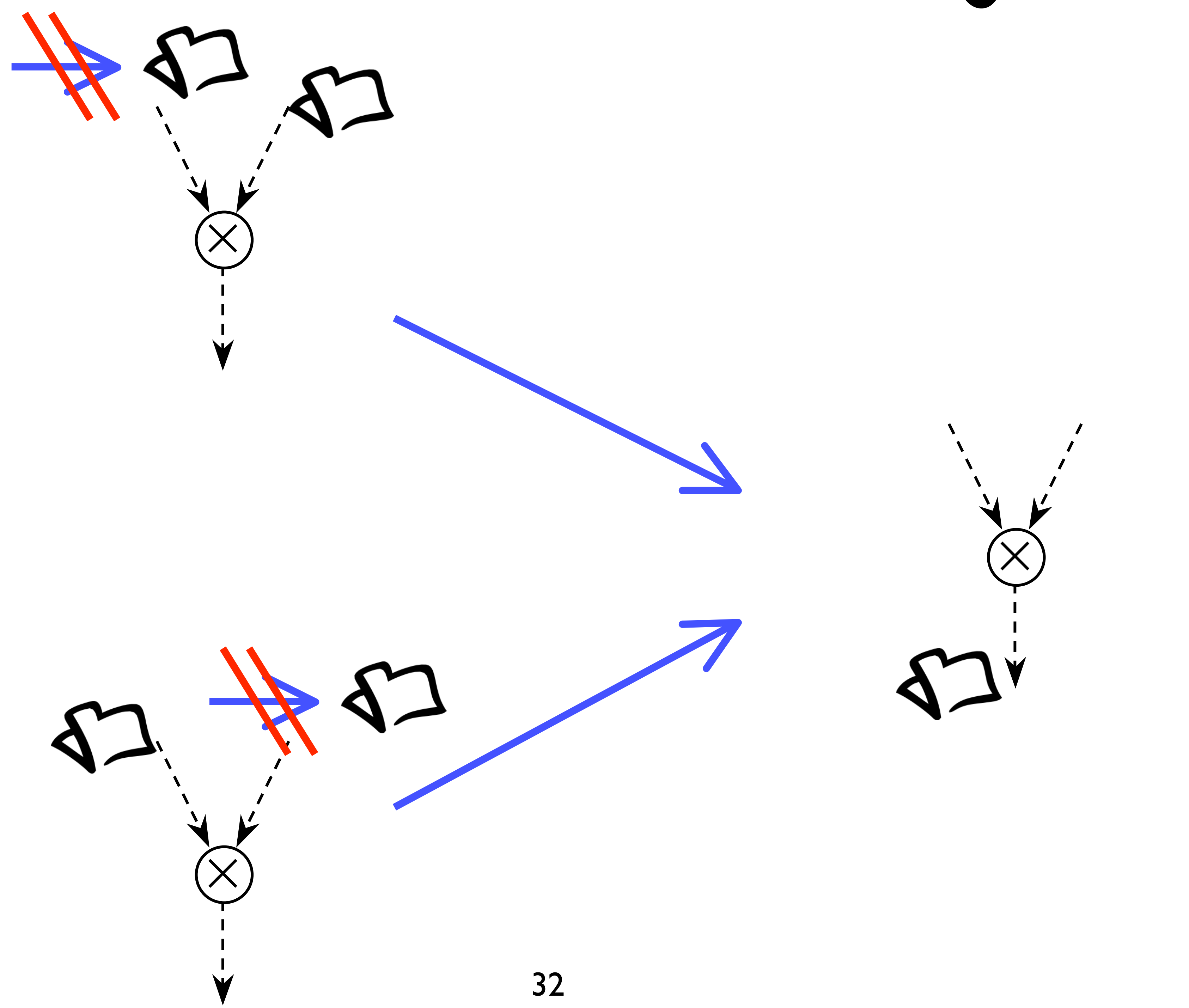
Folder-passing semantics: AND-split



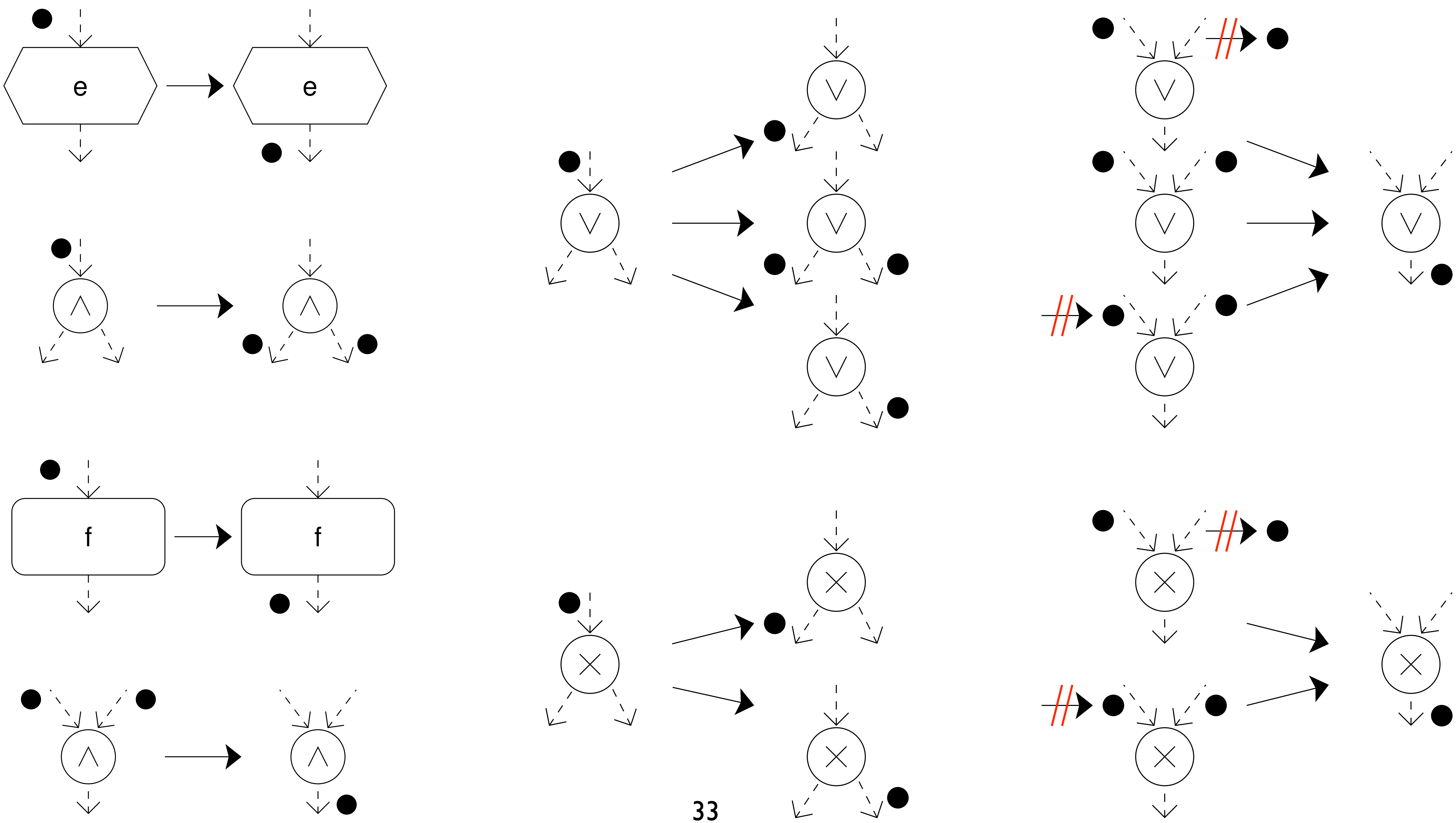
Folder-passing semantics: XOR-split



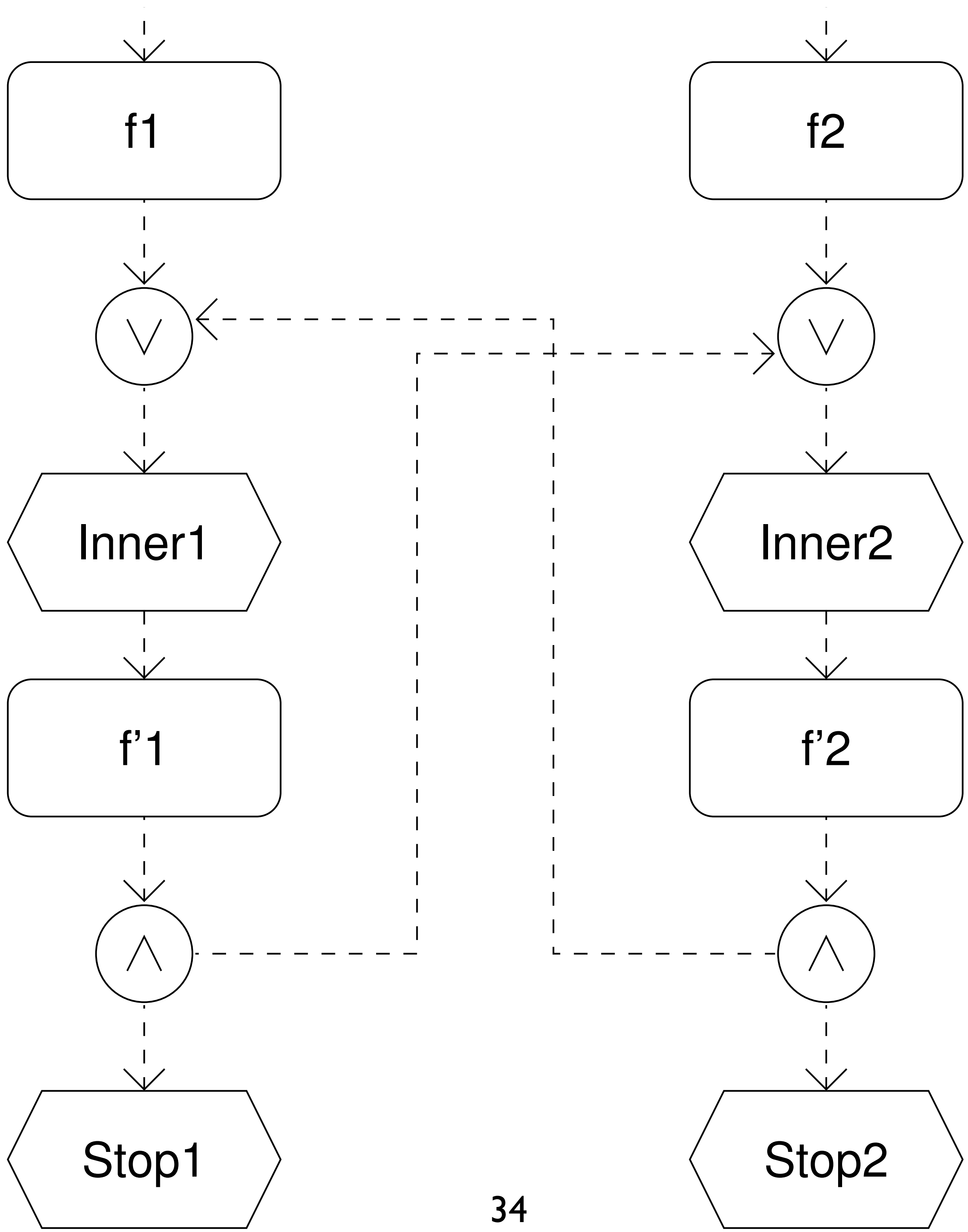
Folder-passing semantics: XOR-join



Folder-semantics in one slide



A vicious circle?



EPC semantics?

Little unanimity around the EPC semantics

Rough verbal description
in the original publication by Scheer (1992)

Later, several attempts to define formal semantics
(assigning different meanings to the same EPC)

Discrepancies typically stem from the interpretation
of (X)OR connectors (in particular, join case)
Other issues: unclear start,
join/split balancing,
alternation between events and functions

Problem with start events

A start event is an event with no incoming arc

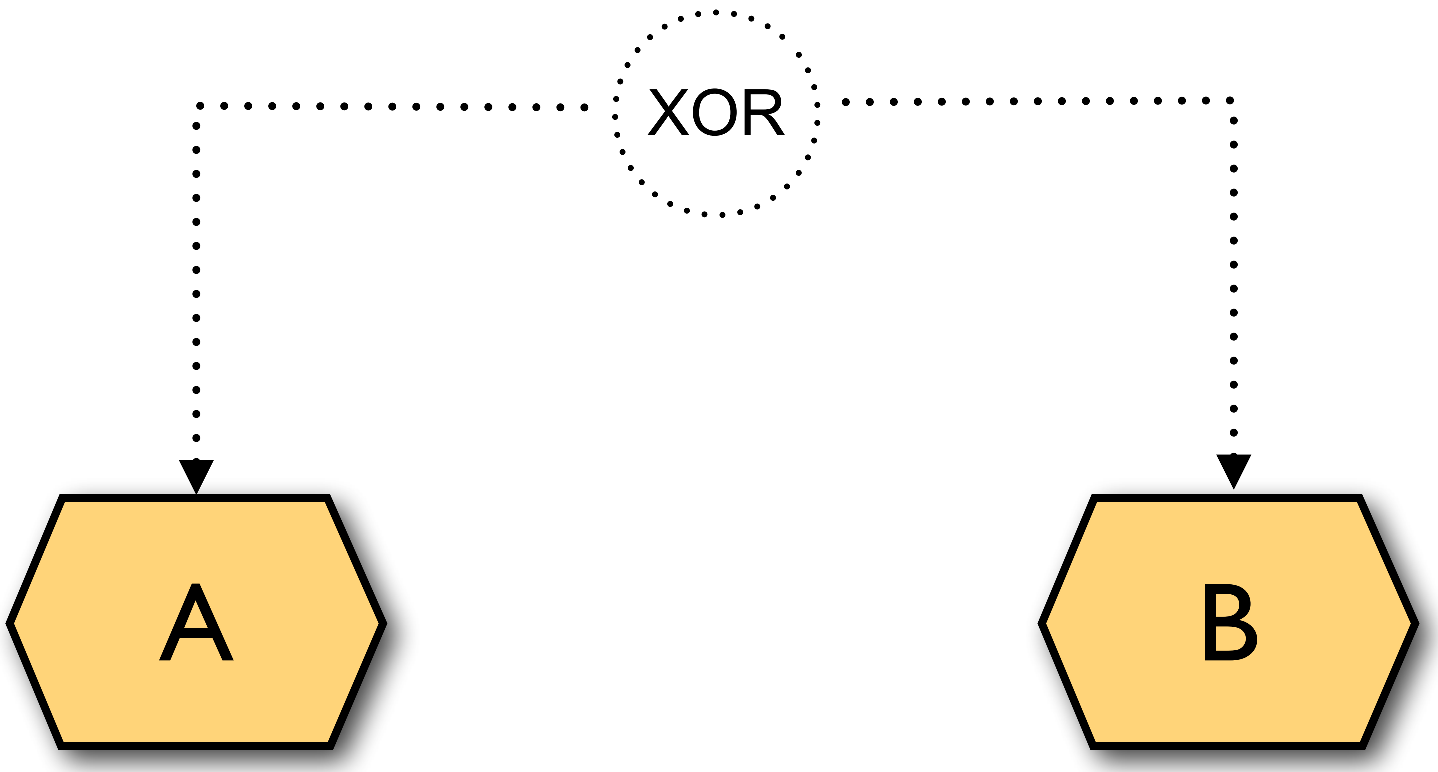
A start event
invokes a new execution of the process template

What if multiple start events occur?

Solution:
Start events are mutually exclusive
(as if they were preceded by an implicit XOR split)

Problem with start events: solution

hypothetical / implicit split



Problem with alternation

From empirical studies:
middle and upper management people consider strict alternation between events and functions as too restrictive:
they find it hard to identify the necessary events at the abstract level of process description they are working at

Solution:
It is safe to drop the requirement about alternation
(dummy events might always be added later)

Every join has a split

observation:
Every join has at least one **corresponding** split
(i.e. a split for which there is a path
from either output to the input of the join)

proof sketch:
we trace backward the paths
leading to the join from start events;
if the start events coincide there is a split node in the path;
if start events differ, the candidate split is the implicit XOR

Problem with corresponding splits

The semantics of a join often depends on the nature of the corresponding split

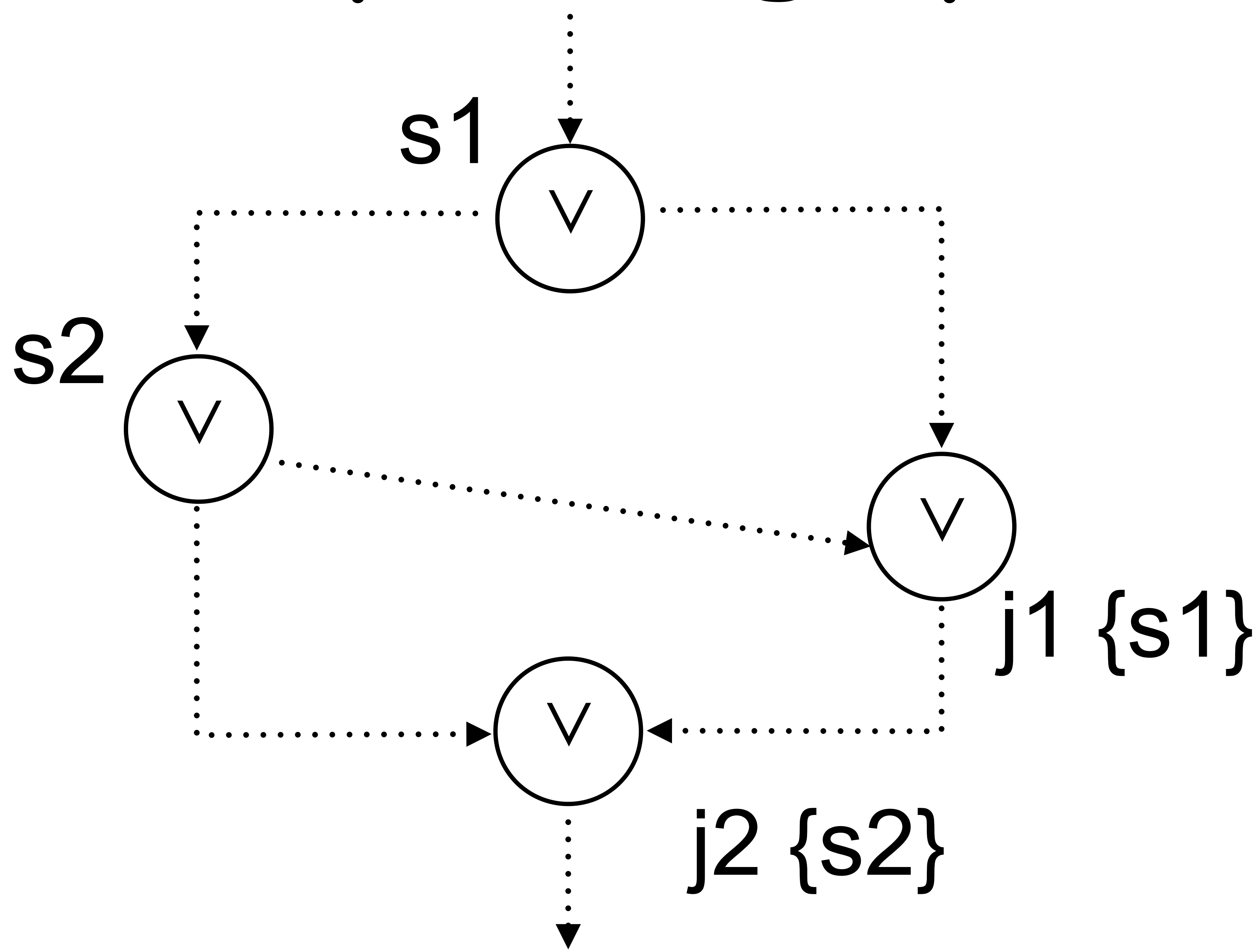
But:

1) there can be **more candidates** to corresponding split
2) and they can have **different type** than the join

candidates of the same type of the join are called **matching** split

Some suggested to have a flag that denotes the corresponding split

Tagging corresponding splits



Problem with OR join

If an OR join has a **matching split**, the semantics is usually:
"wait for the completion of all paths activated by the matching split"

If there is no matching split, some policy must be applied:

wait-for-all: wait for the completion of all *activated* paths
(default semantics, because it coincides with that of a matching split)

first-come: wait only for the path that is completed first
and ignore the second

every-time: trigger the outgoing path on each completion
(the outgoing path can be activated multiple times)

Some suggested to have different (trapezoid) symbols or
suitable flags to distinguish the above cases

Problem with XOR join

Similar considerations hold for the XOR join

If a XOR join has a matching split, the semantics is intuitive:
“it blocks if both paths are activated and
it is triggered by the completion of a single activated path”

If there is no matching split:
all feasible interpretations that do not involve blocking are already covered by the OR (wait-for-all, first-come, every-time)
and **contradict the exclusivity** of the XOR
(a token from one path can be accepted only if we make sure that no second token will arrive via the other path)

Some suggest to just forbid the use of XOR in the unmatched case
(the implicit start split is allowed as a valid match)

Sound EPC diagrams

We transform EPC diagrams to Workflow nets:
the EPC diagram is sound if its net is so

We exploit the formal semantics of nets
to give unambiguous semantics to EPC diagrams

We apply the verification tools we have seen
to check if the net is sound

Translation of EPC to Petri nets

A note about the transformation

We first transform each event, function and connector separately in small net fragments

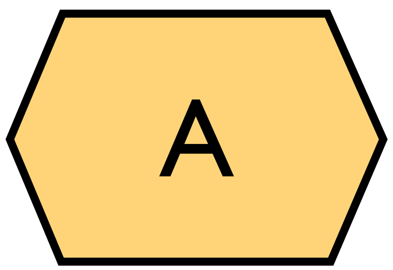
When translating the control flow arcs we may then introduce other places / transitions to preserve the bipartite structure in the net
(no arc allowed between two places,
no arc allowed between two transitions)

We show different translations, depending on whether joins are decorated or not

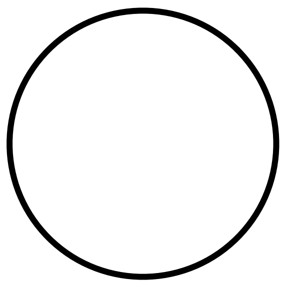
First attempt (decorated EPC)

EPC

Petri net

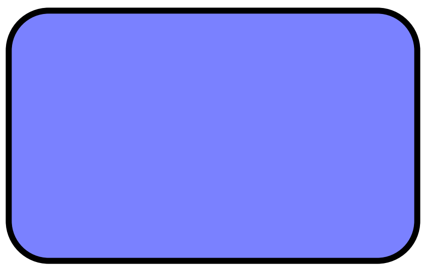


event



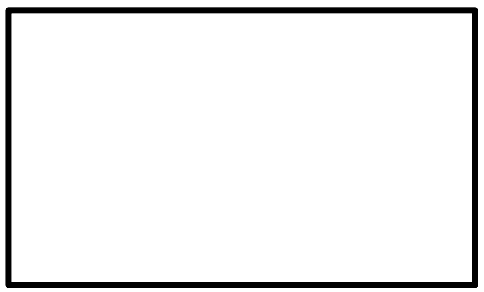
place

EPC



function

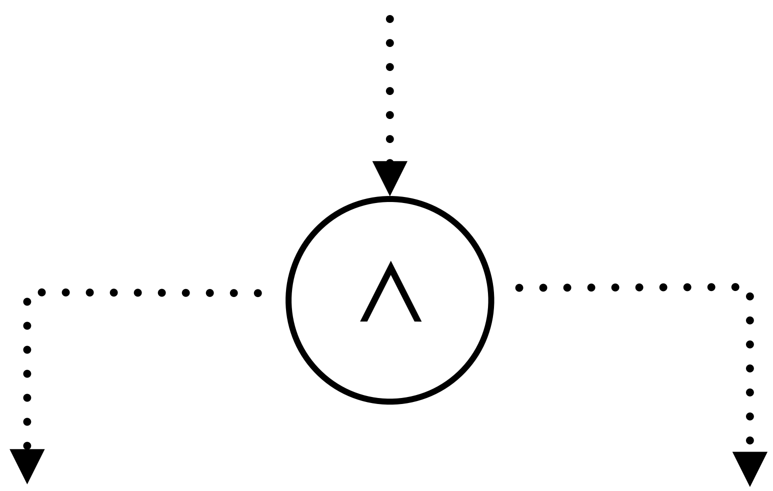
Petri net



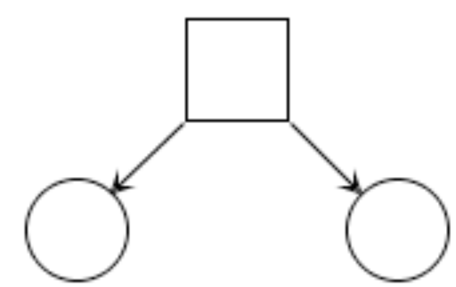
transition

EPC

Petri net



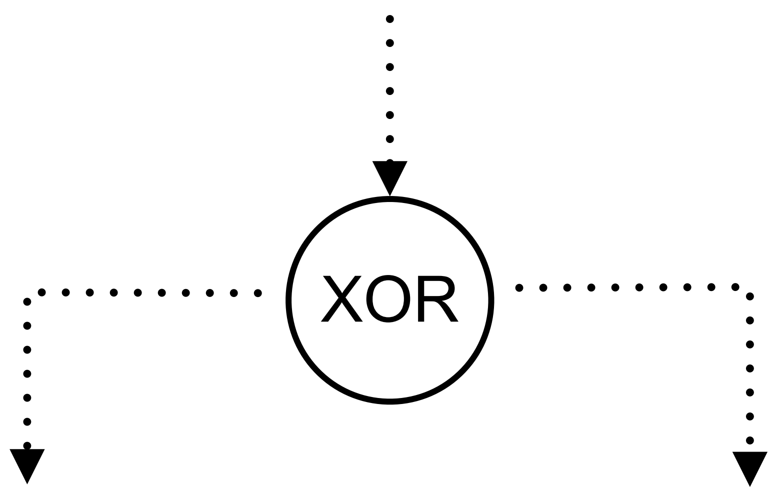
AND split

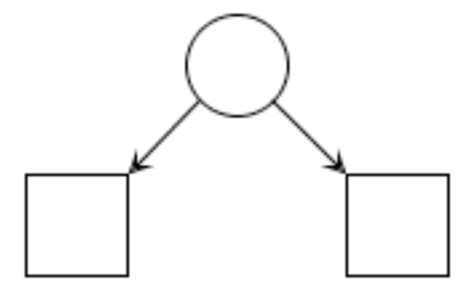


net

EPC

Petri net



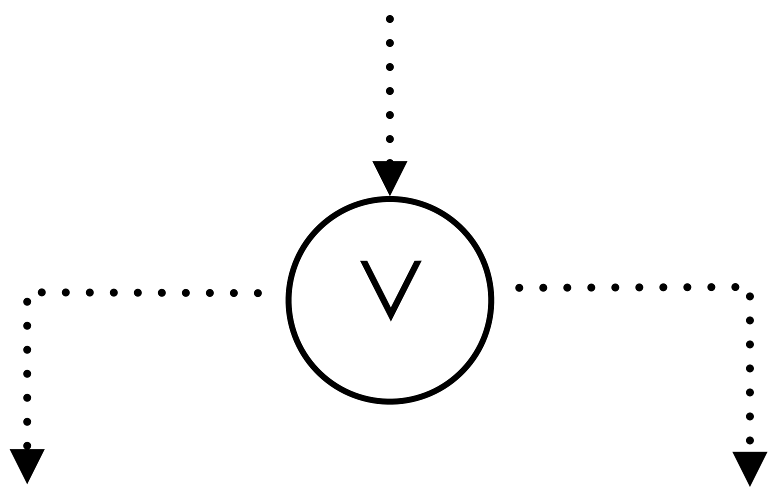


XOR split

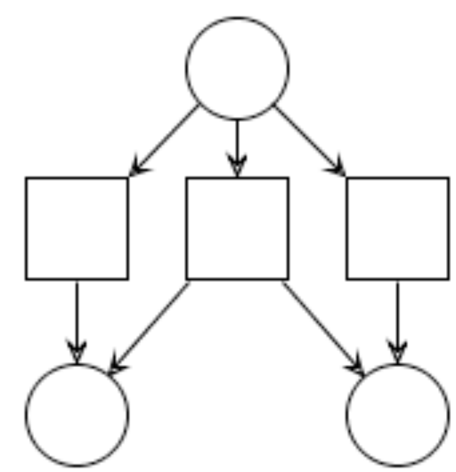
net

EPC

Petri net

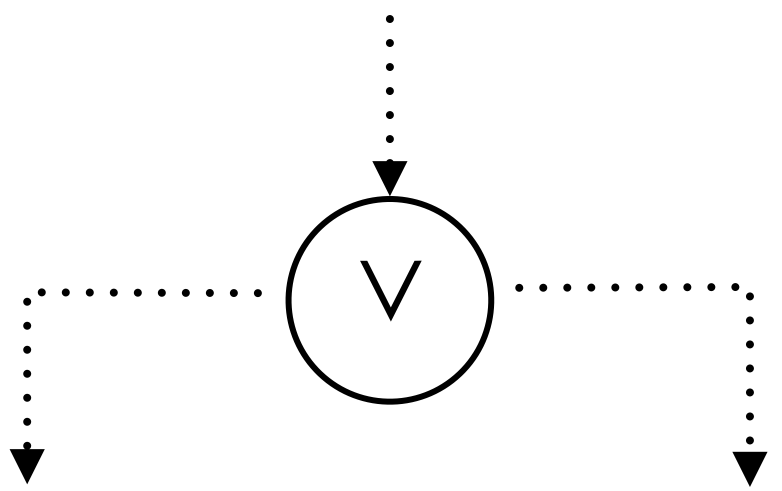


OR split



net

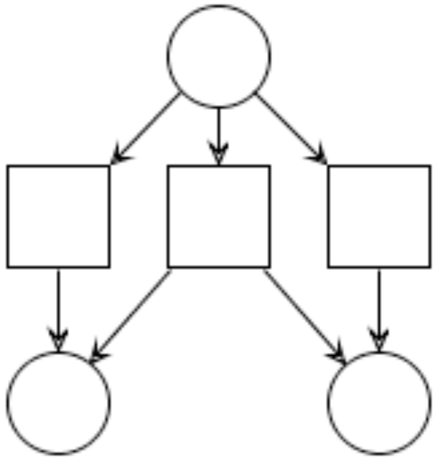
EPC



OR split

Petri net

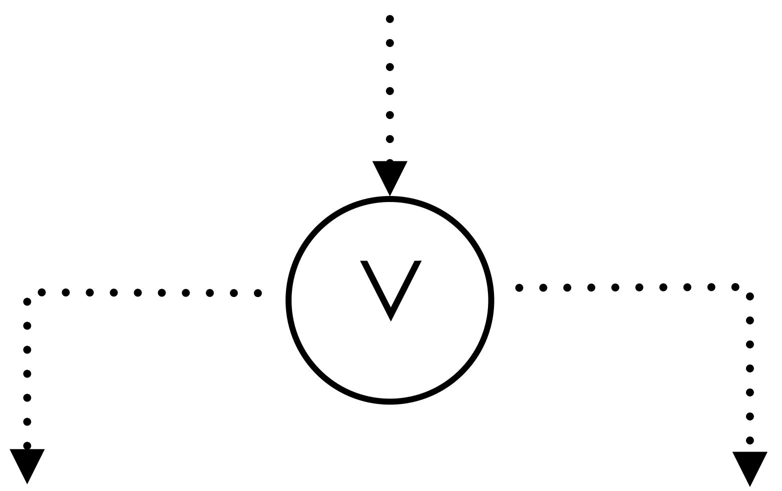
xor
+
and

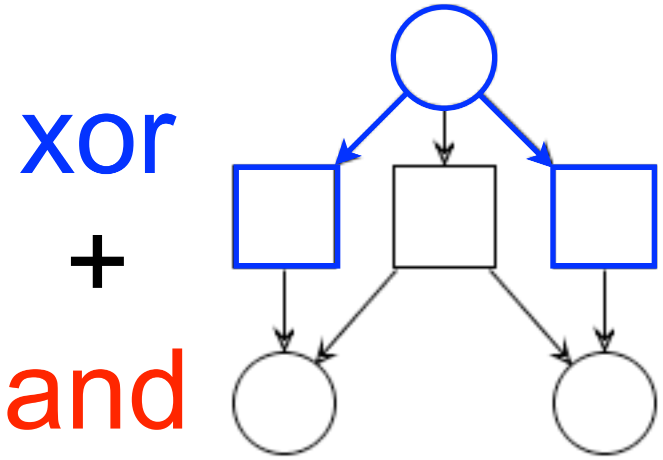


net

EPC

Petri net



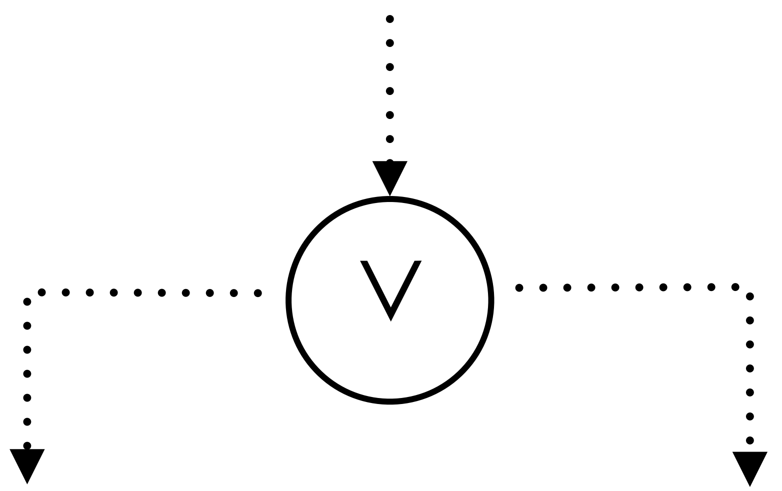


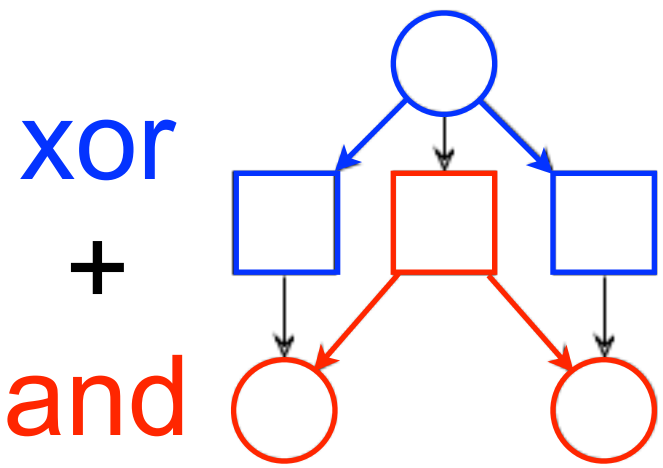
OR split

net

EPC

Petri net



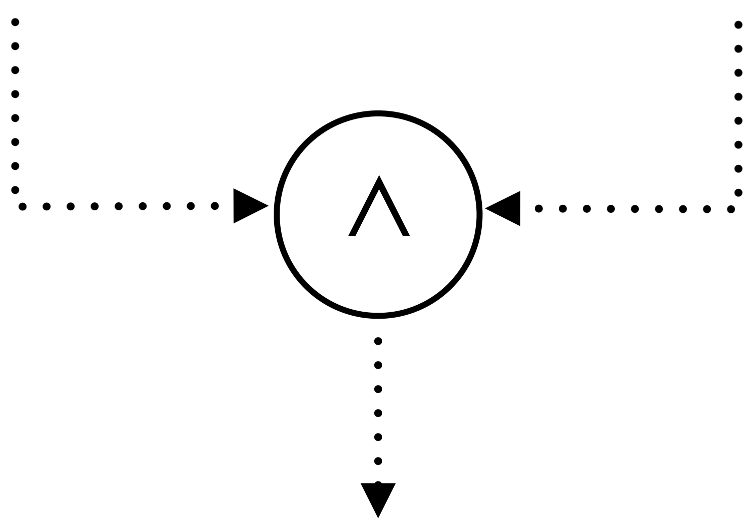


OR split

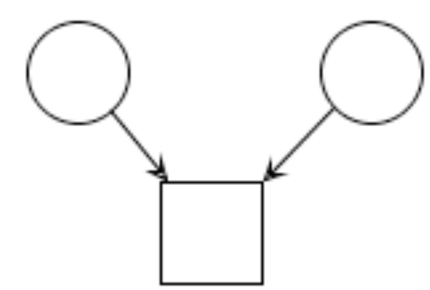
net

EPC

Petri net



AND join



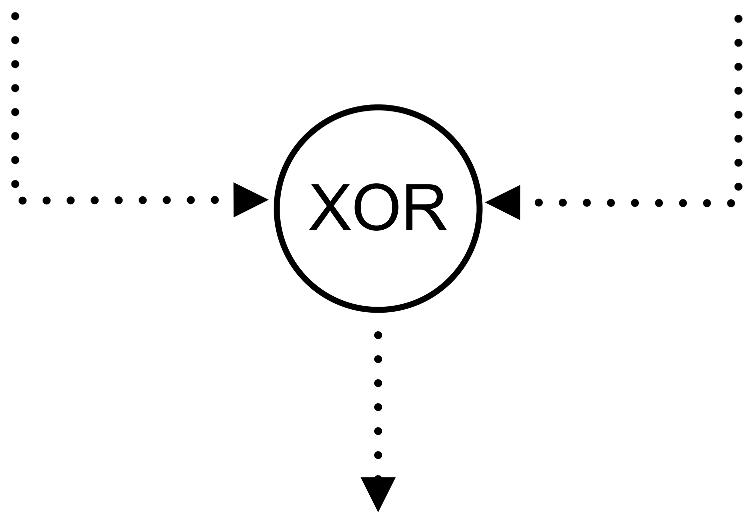
net

EPC

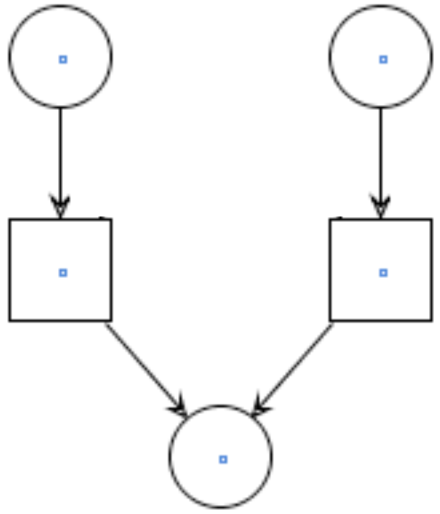
Petri net

corresponding split

?

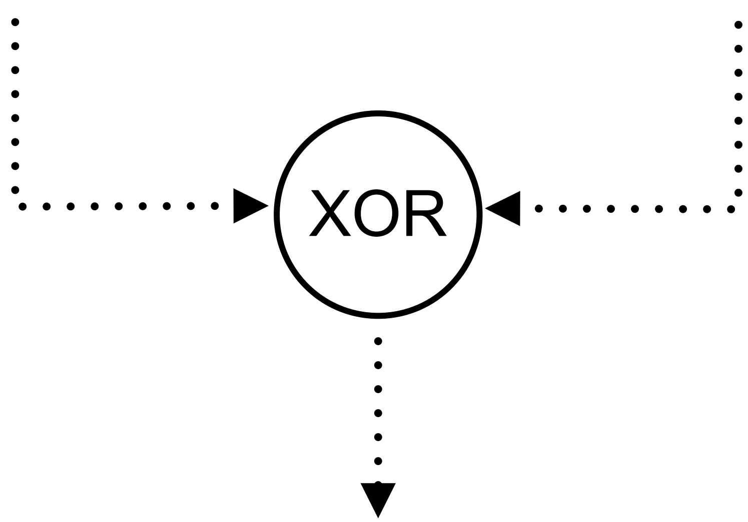


XOR join



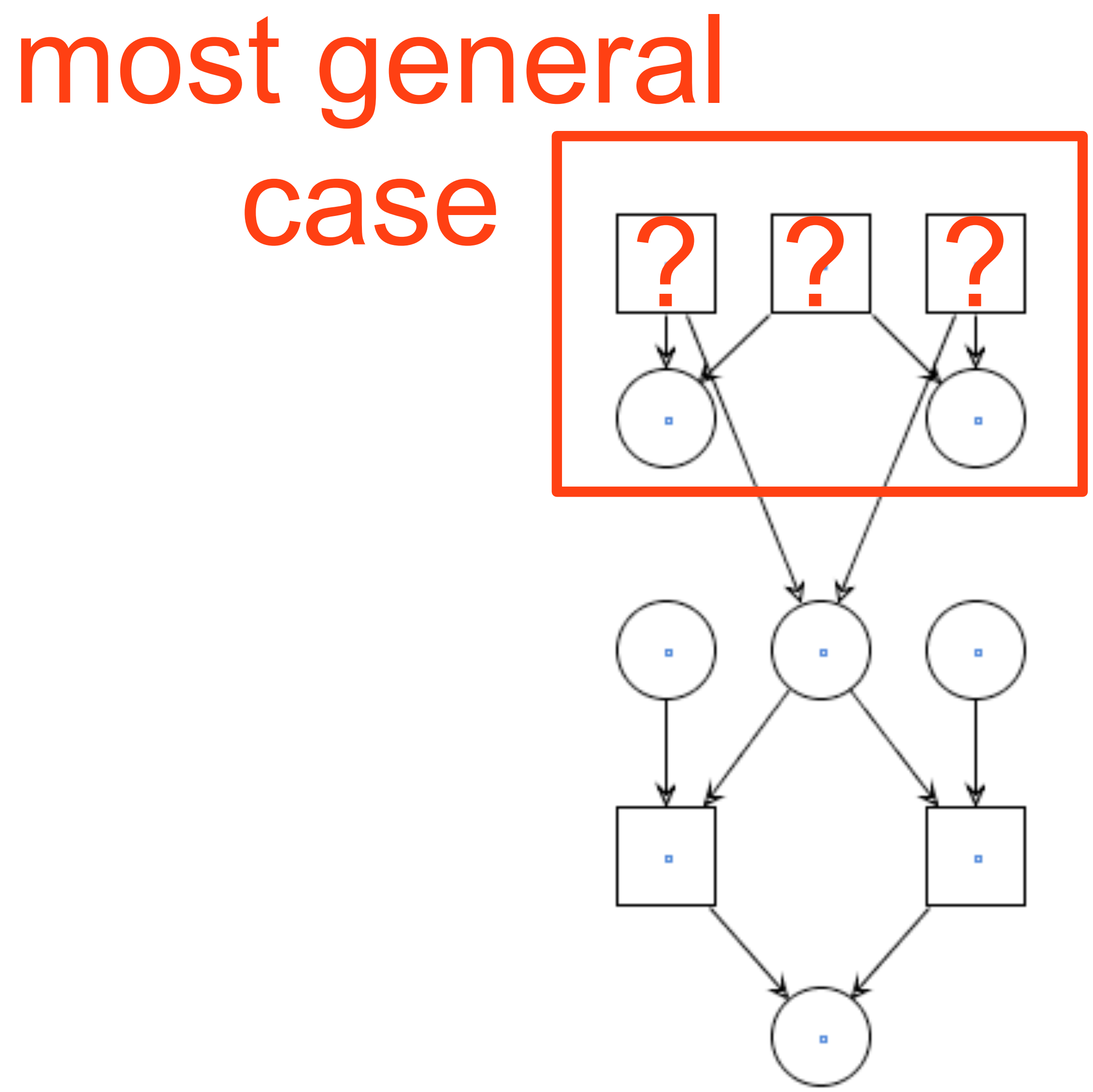
net

EPC



XOR join

Petri net

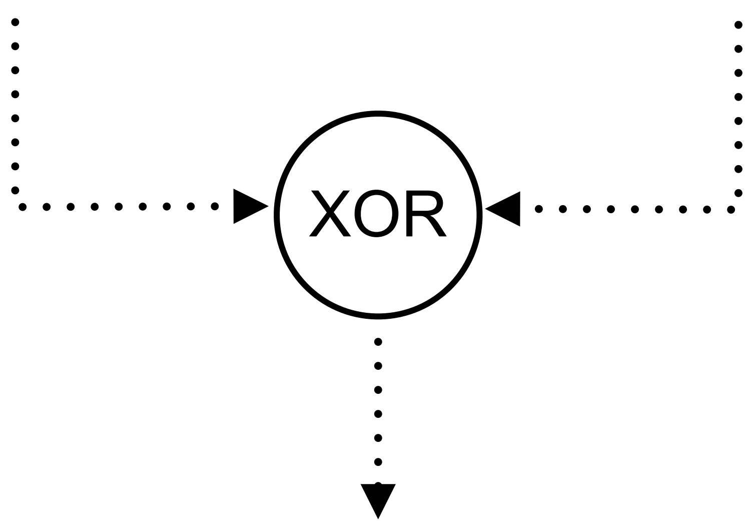


net

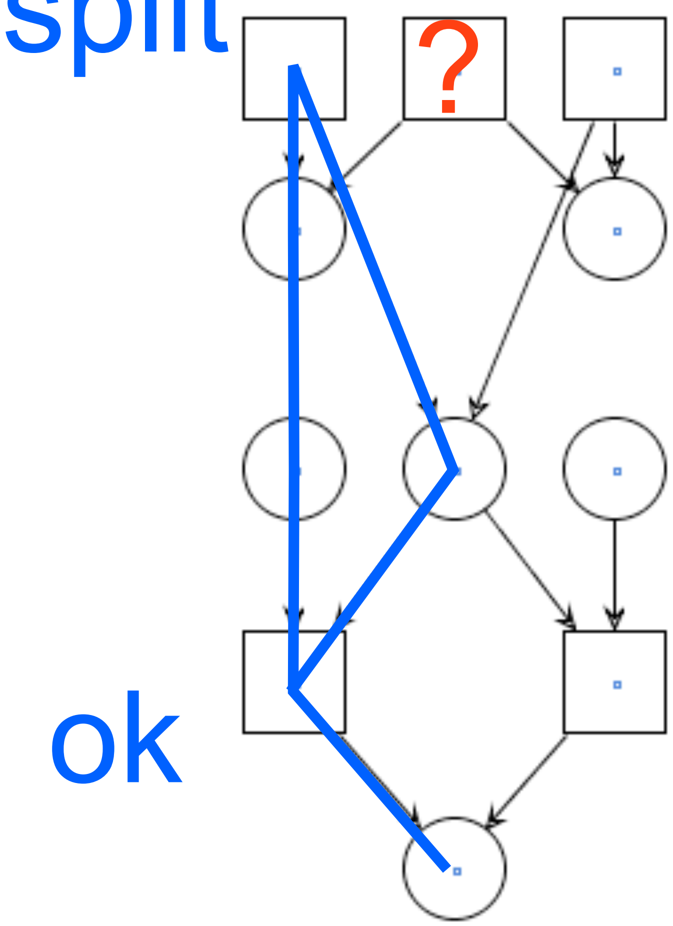
EPC

Petri net

corresponding XOR/OR split



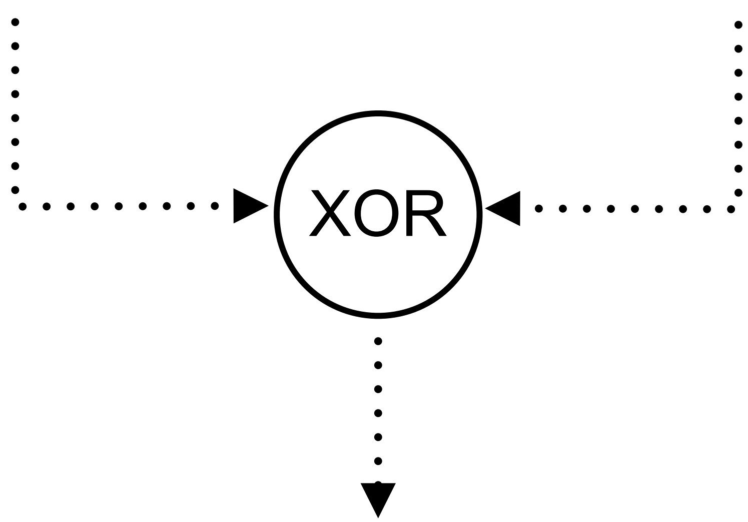
XOR join



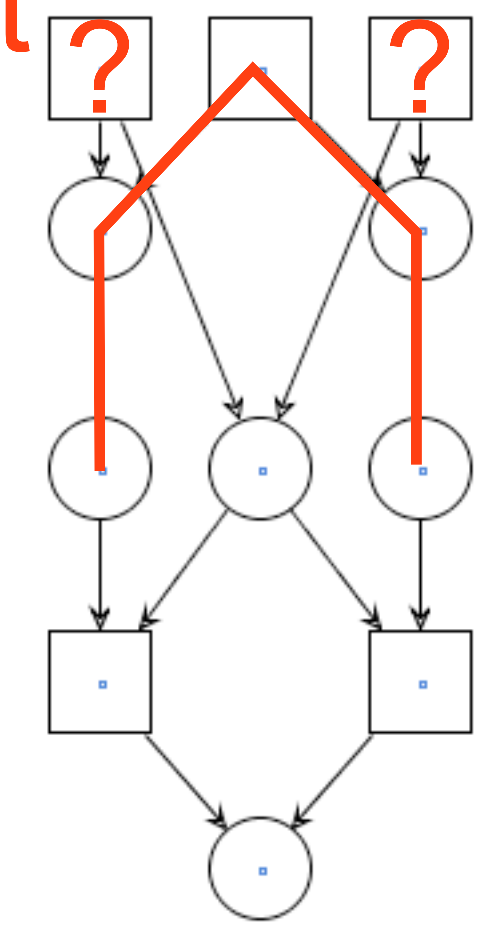
net

EPC

Petri net



XOR join

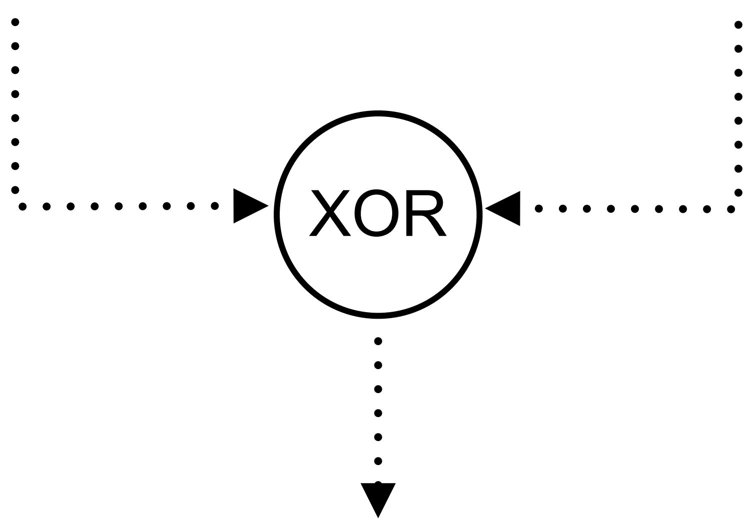


net

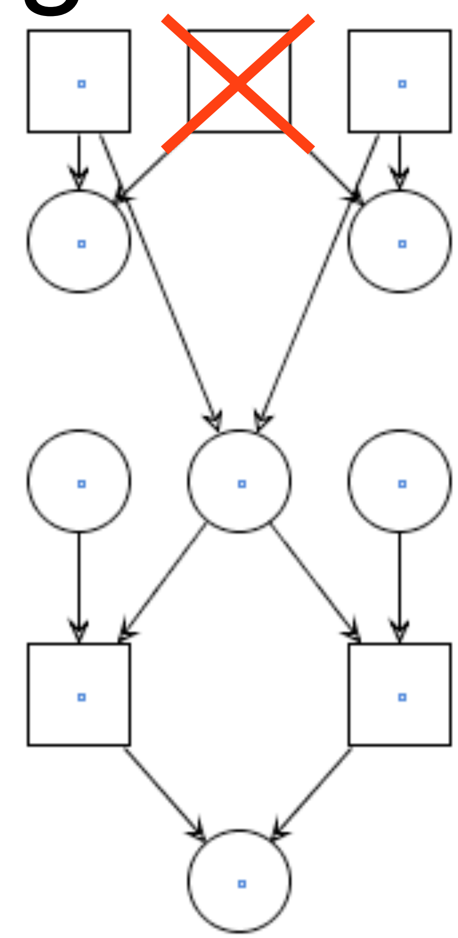
EPC

Petri net

better to have
a corresponding
XOR split!



XOR join



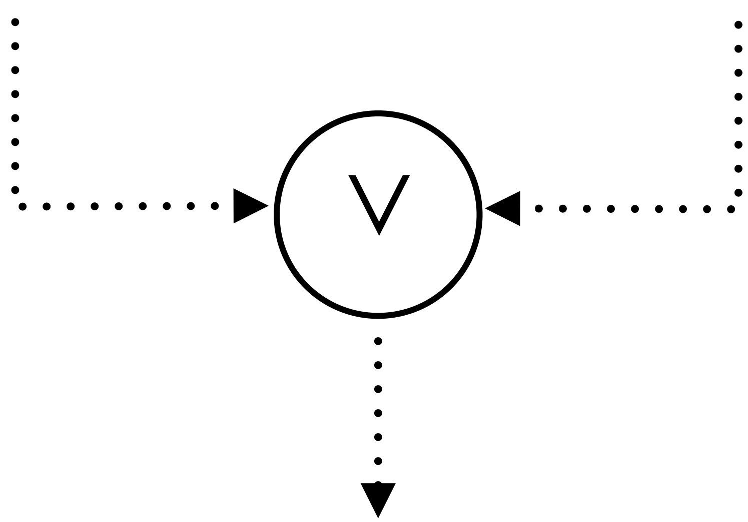
net

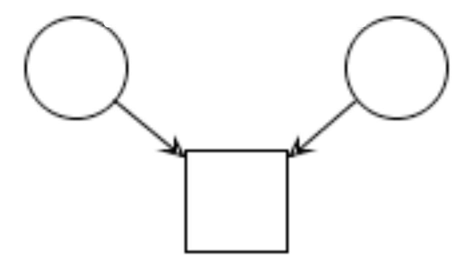
EPC

Petri net

corresponding
split

?



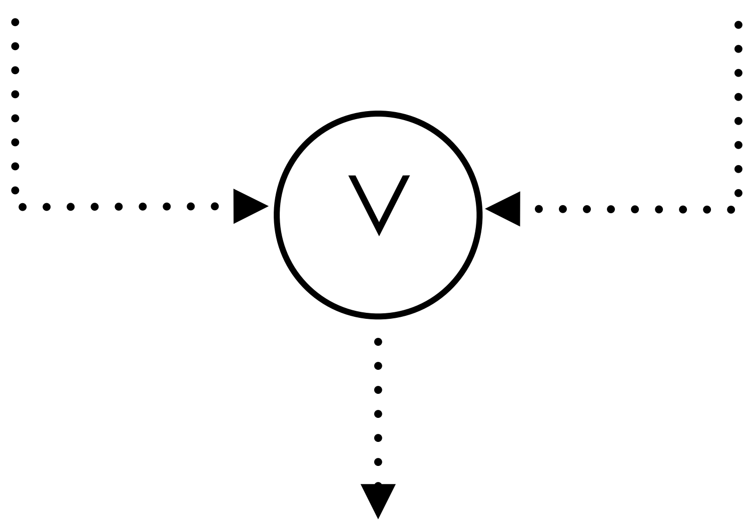


net

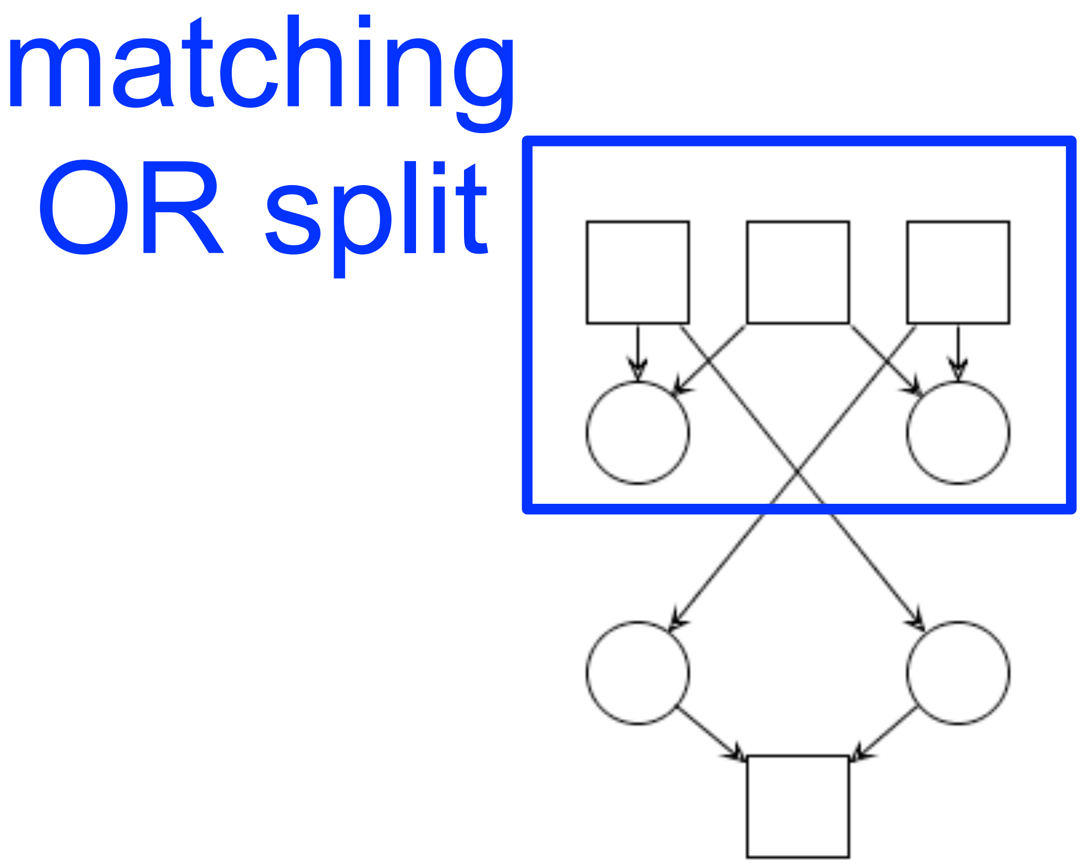
OR join

EPC

Petri net



OR join
with
matched OR split

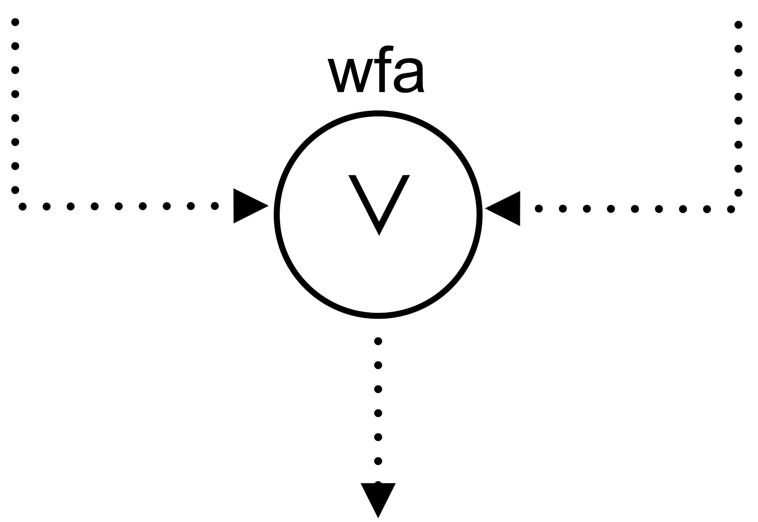


net

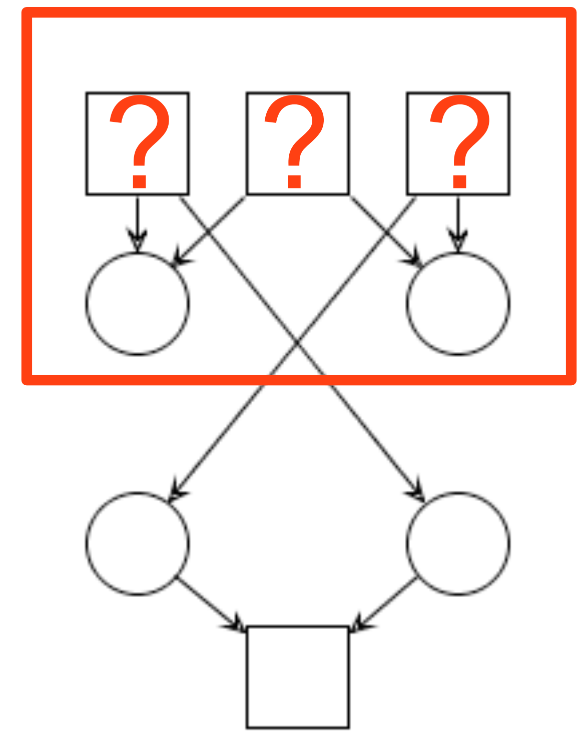
EPC

Petri net

mismatched corresponding split:
most general case



OR join
wait-for-all
(mismatched)

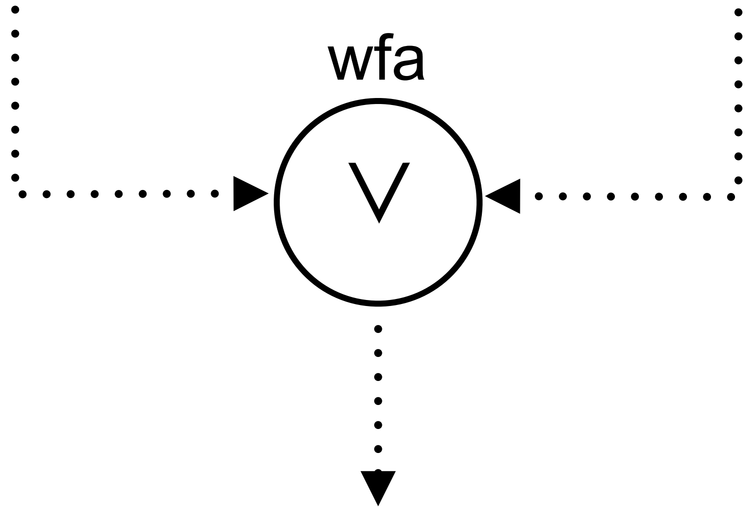


net

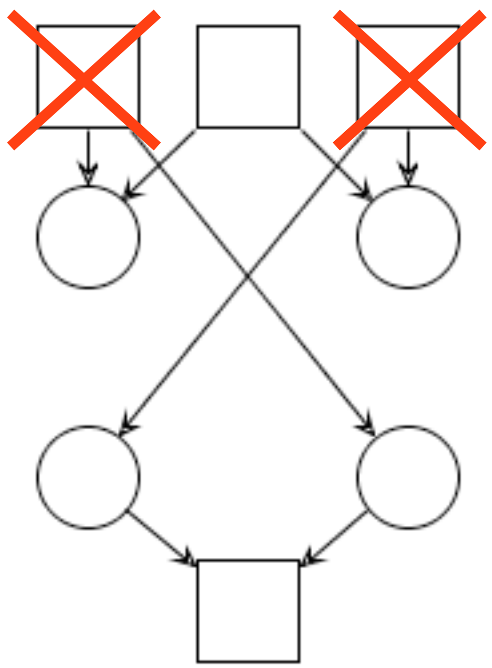
EPC

Petri net

corresponding
AND split



OR join
wait-for-all
(mismatched)

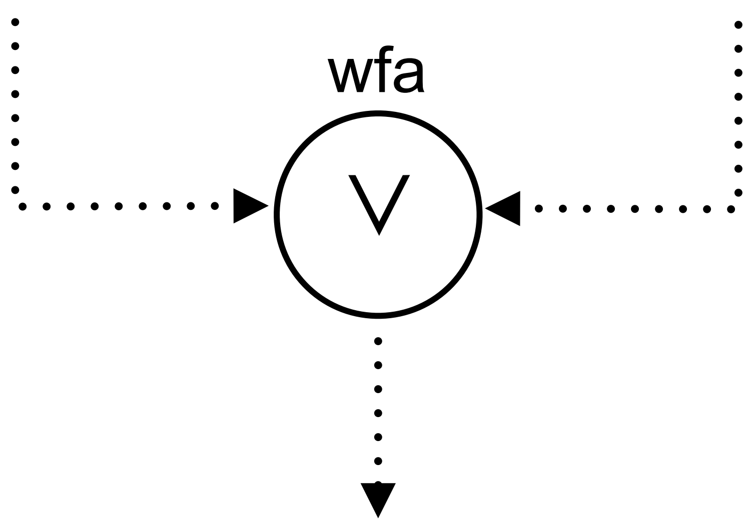


net

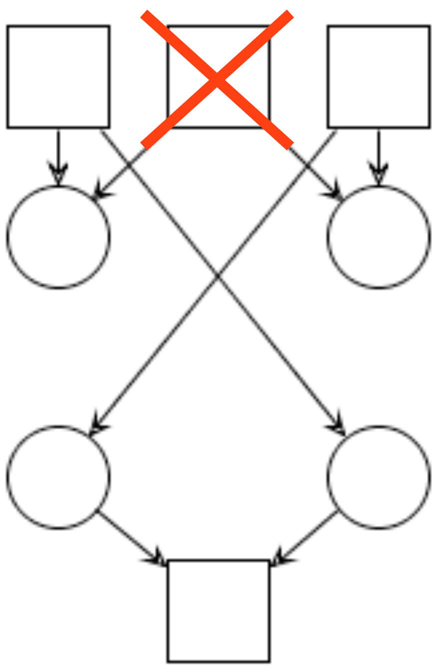
EPC

Petri net

corresponding
XOR split



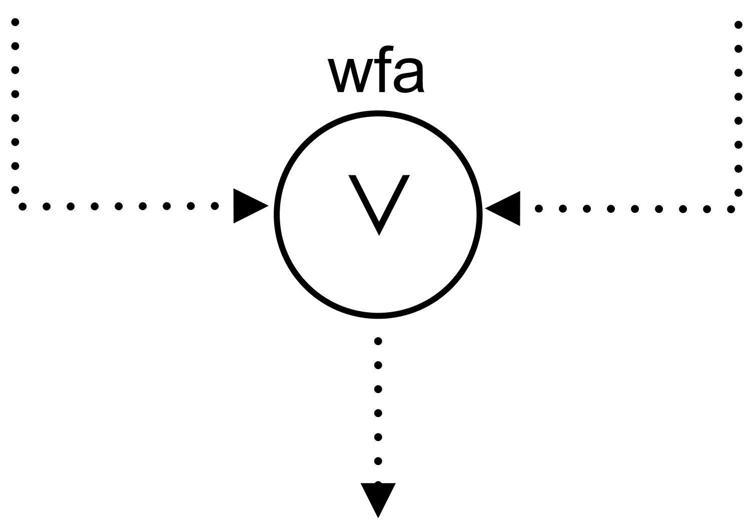
OR join
wait-for-all
(mismatched)



net

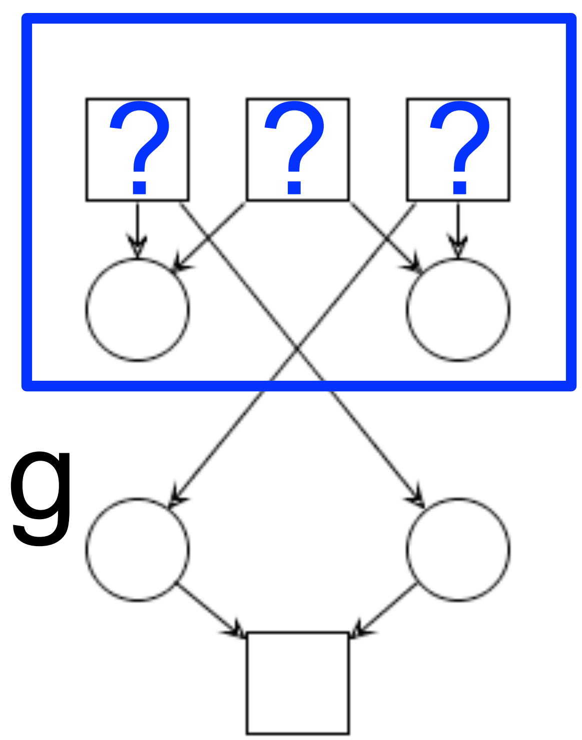
EPC

Petri net



OR join
wait-for-all
(mismatched)

wfa
works well
with any
corresponding
split

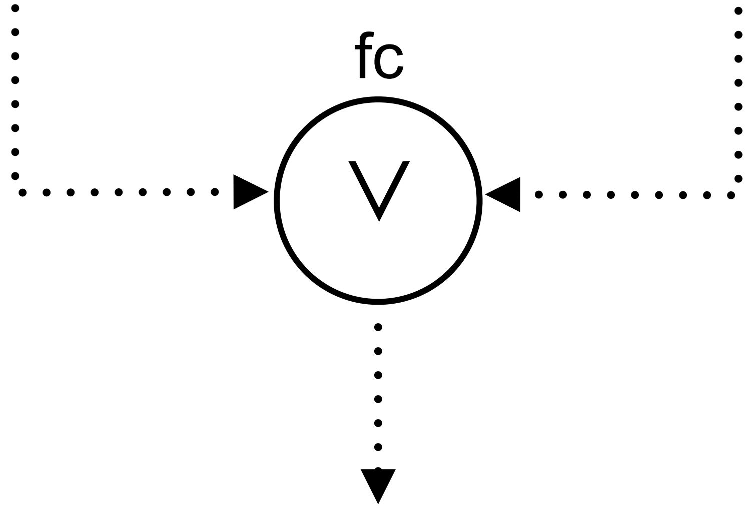


net

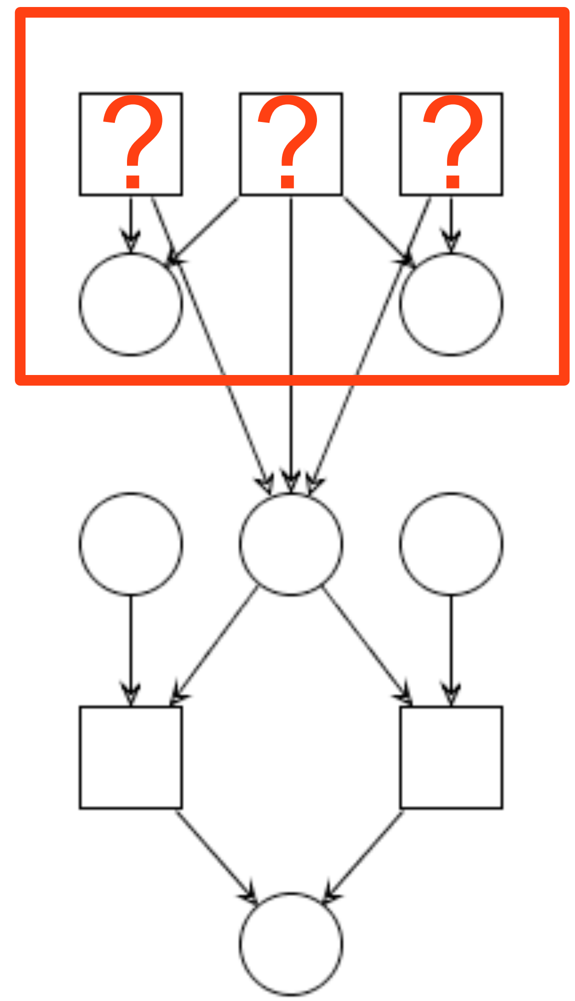
EPC

Petri net

mismatched corresponding split:
most general
case



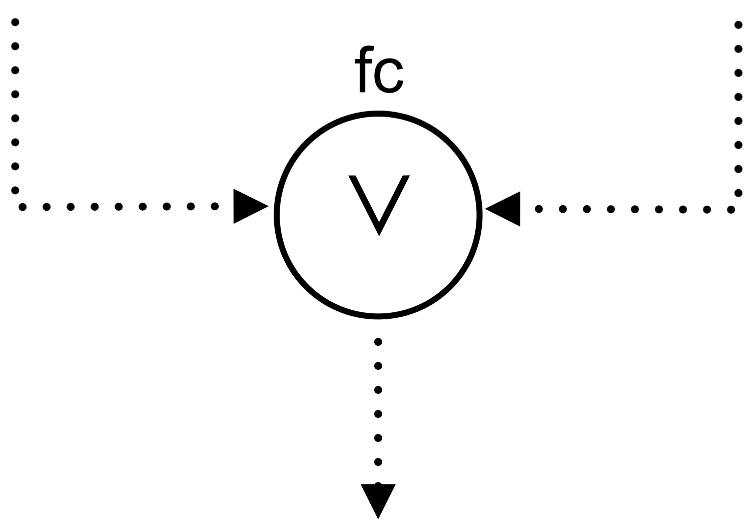
OR join
first-come
(mismatched)



net

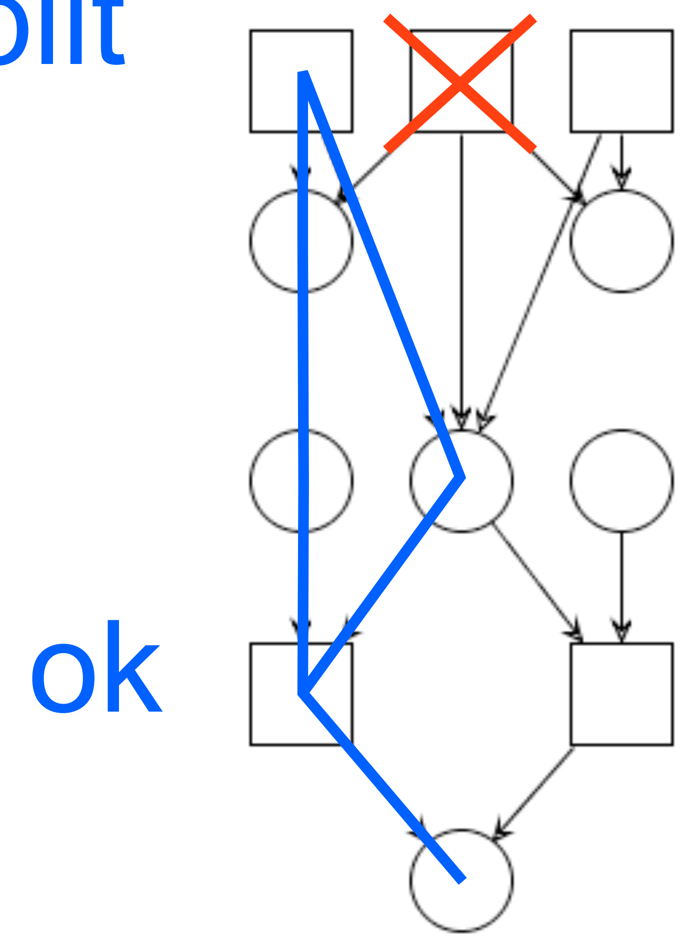
EPC

Petri net



OR join
first-come
(unmatched)

corresponding
XOR split

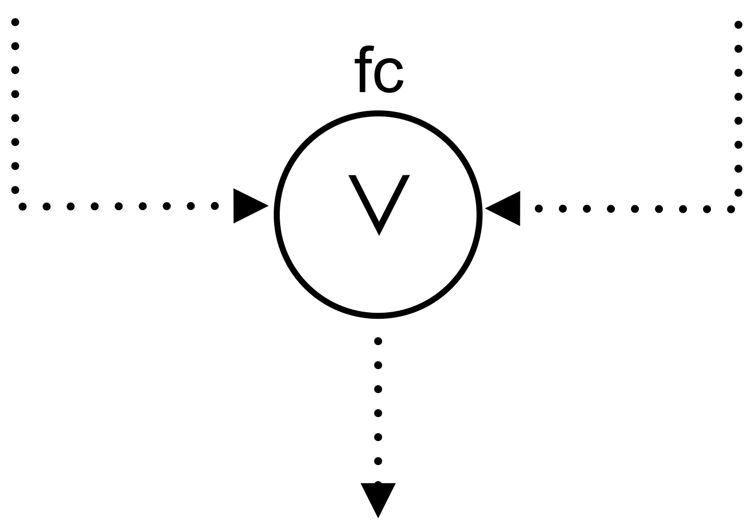


net

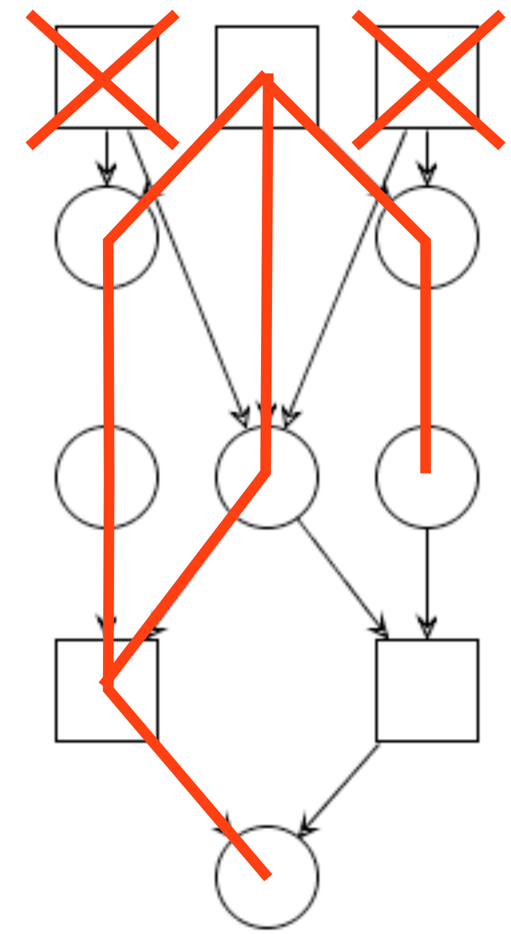
EPC

Petri net

corresponding
AND split



OR join
first-come
(unmatched)



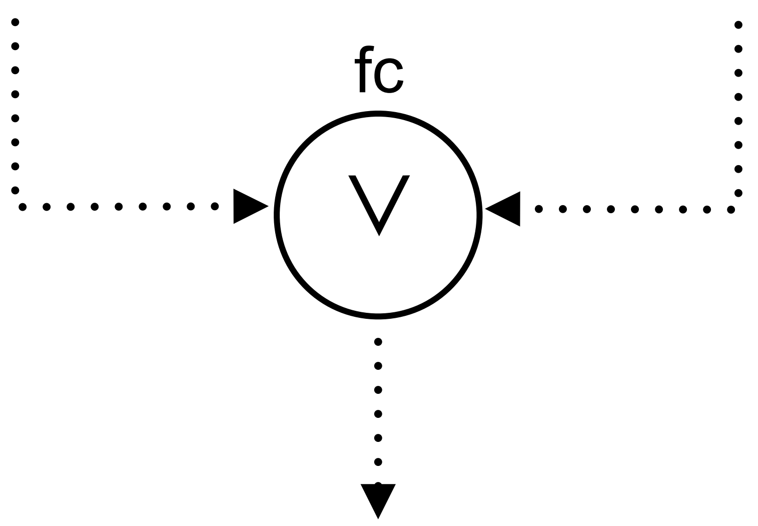
pending
token!

net

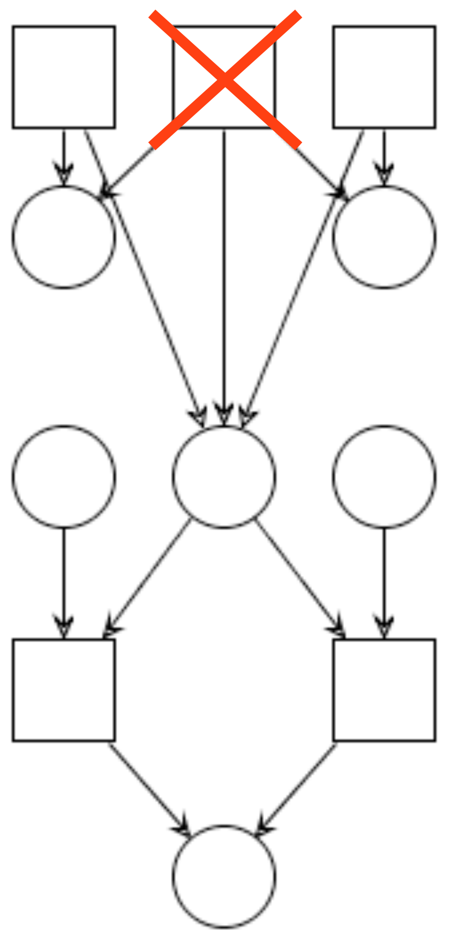
EPC

Petri net

fc:
better to have
a corresponding
XOR split!



OR join
first-come
(mismatched)

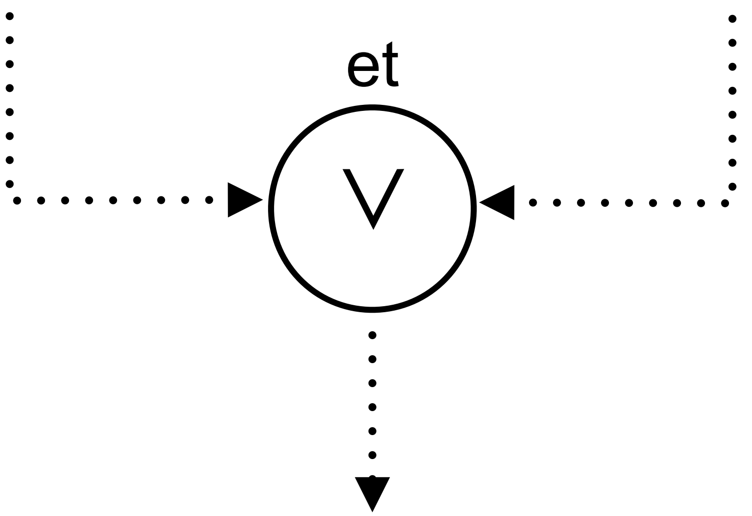


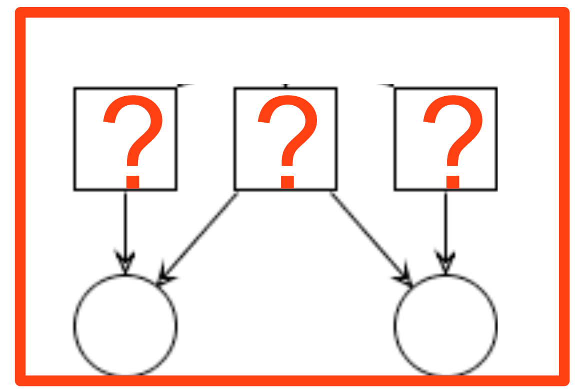
net

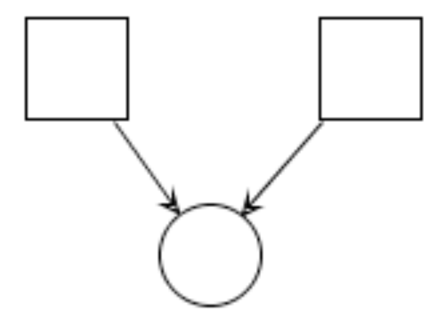
EPC

Petri net

mismatched corresponding split:
most general
case







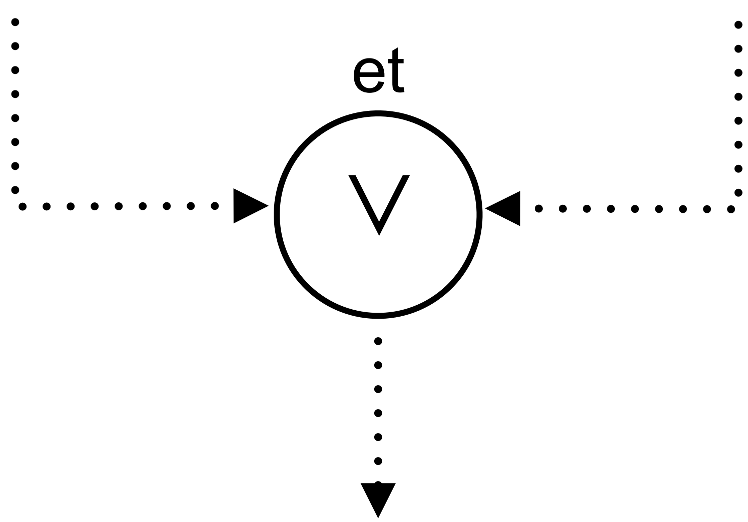
OR join
every-time
(mismatched)

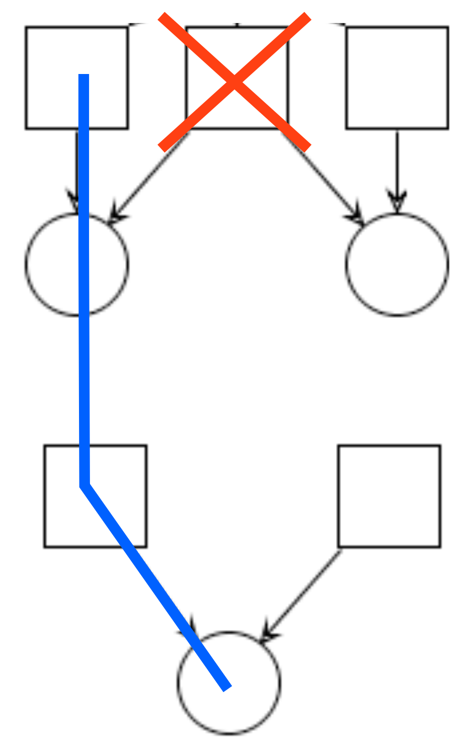
net

EPC

Petri net

corresponding
XOR split





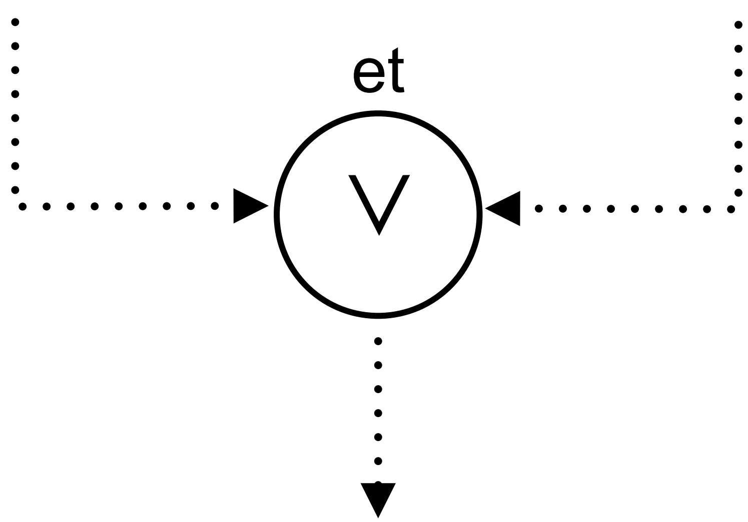
ok

OR join
every-time
(mismatched)

net

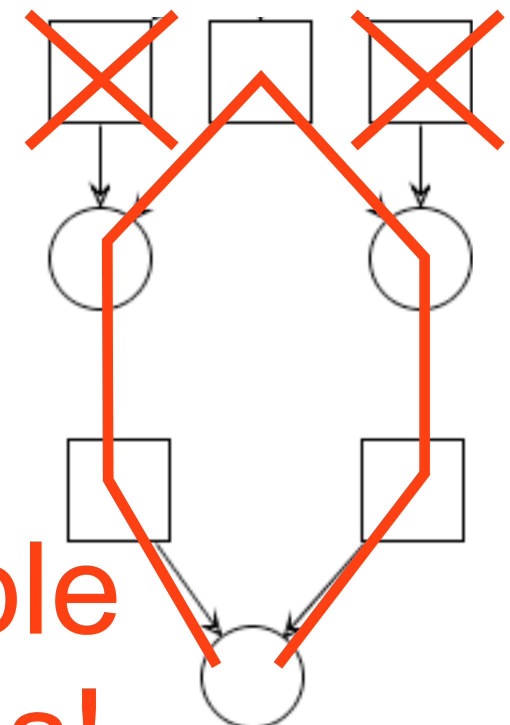
EPC

Petri net



OR join
every-time
(unmatched)

corresponding
AND split



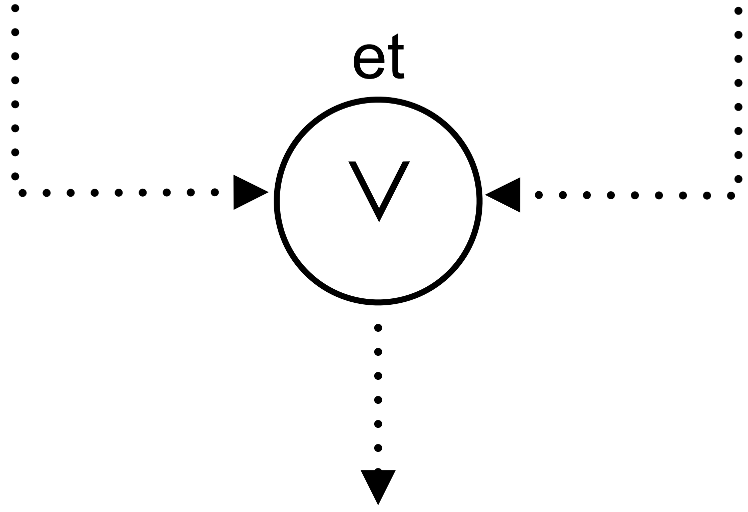
multiple
tokens!

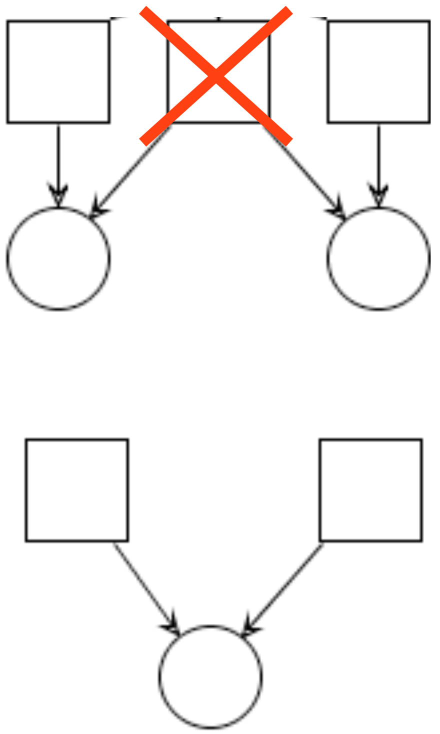
net

EPC

Petri net

et:
better to have
a corresponding
XOR split!



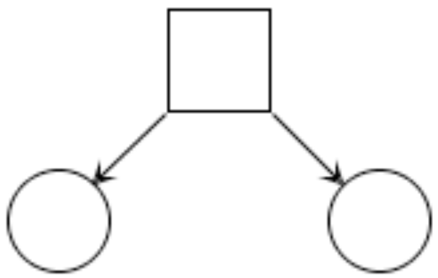


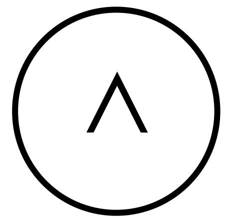
OR join
every-time
(mismatched)

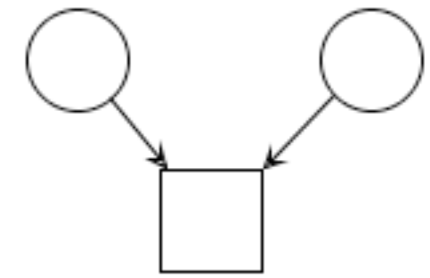
net

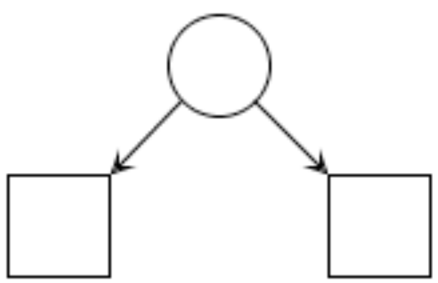
split

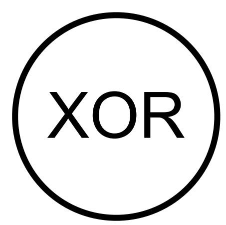
join

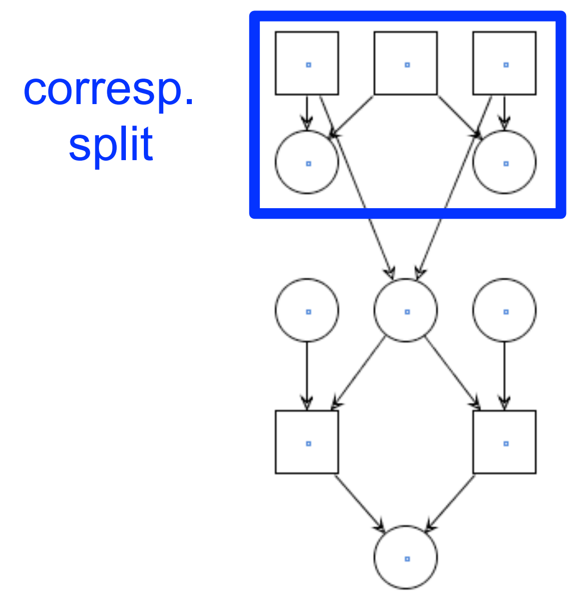


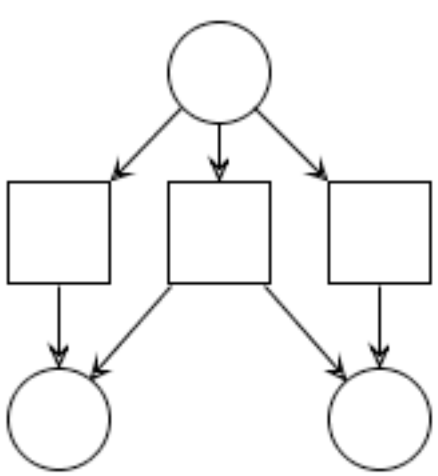

∧

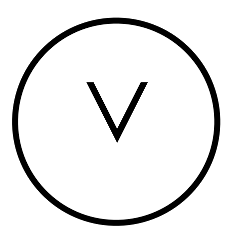


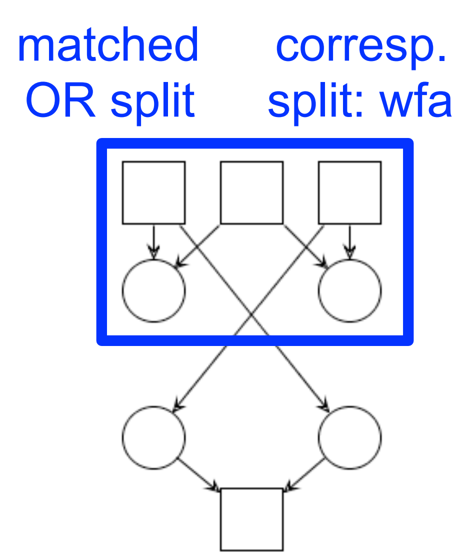


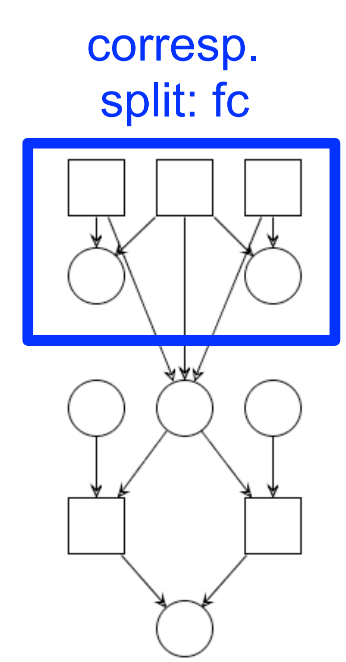

XOR

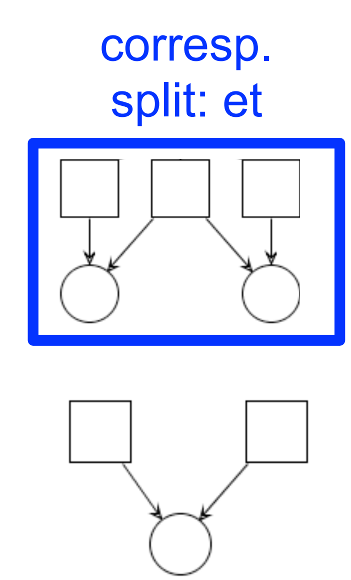

corresp.
split




∨

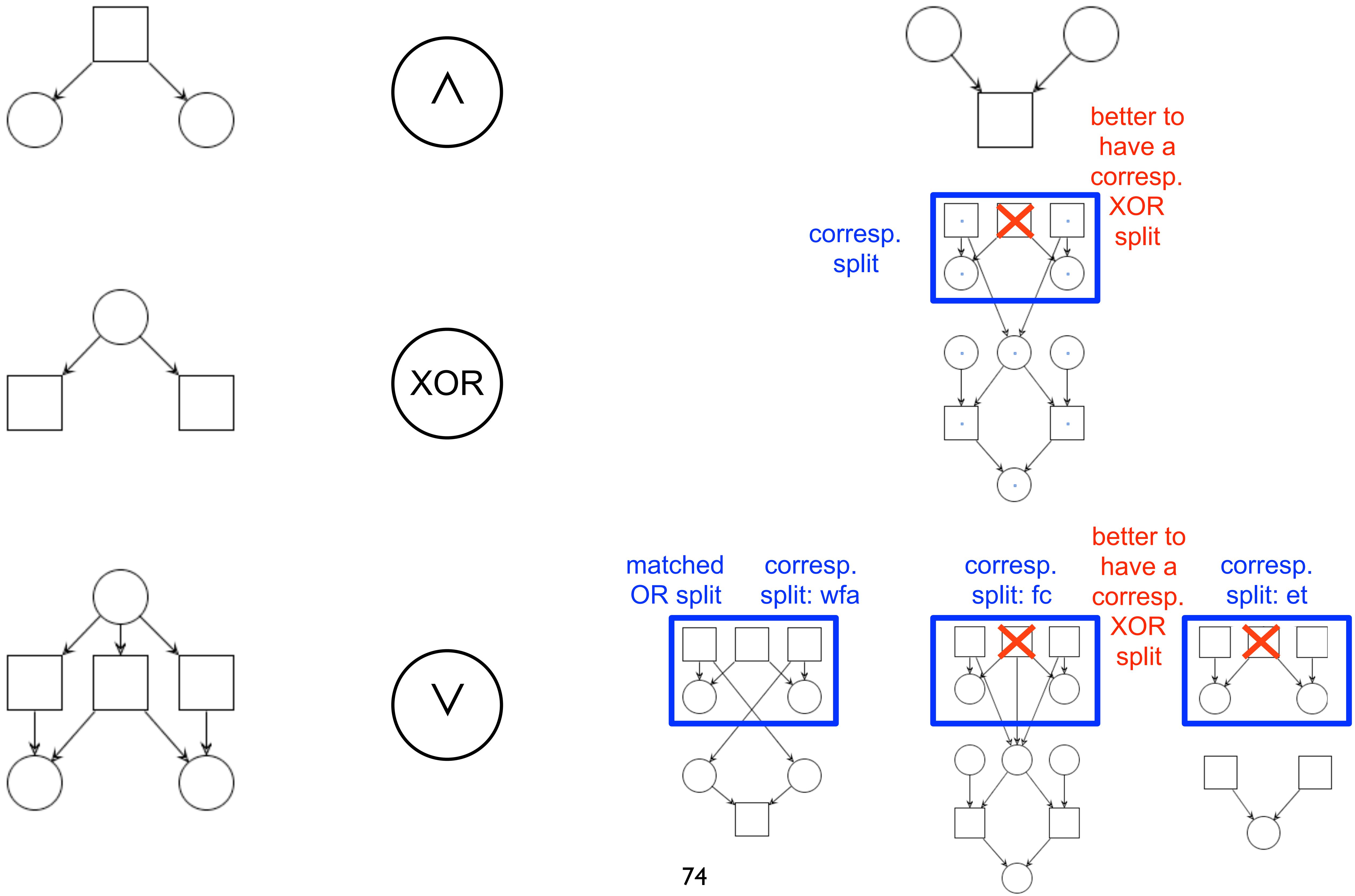

matched
OR split
corresp.
split: wfa


corresp.
split: fc

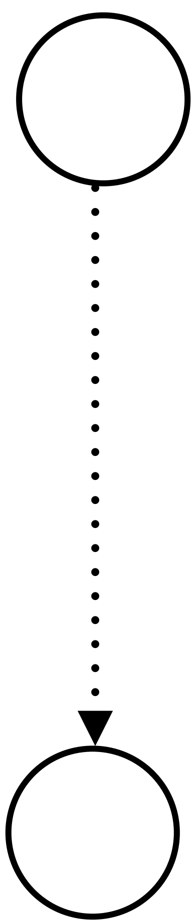

corresp.
split: et

split

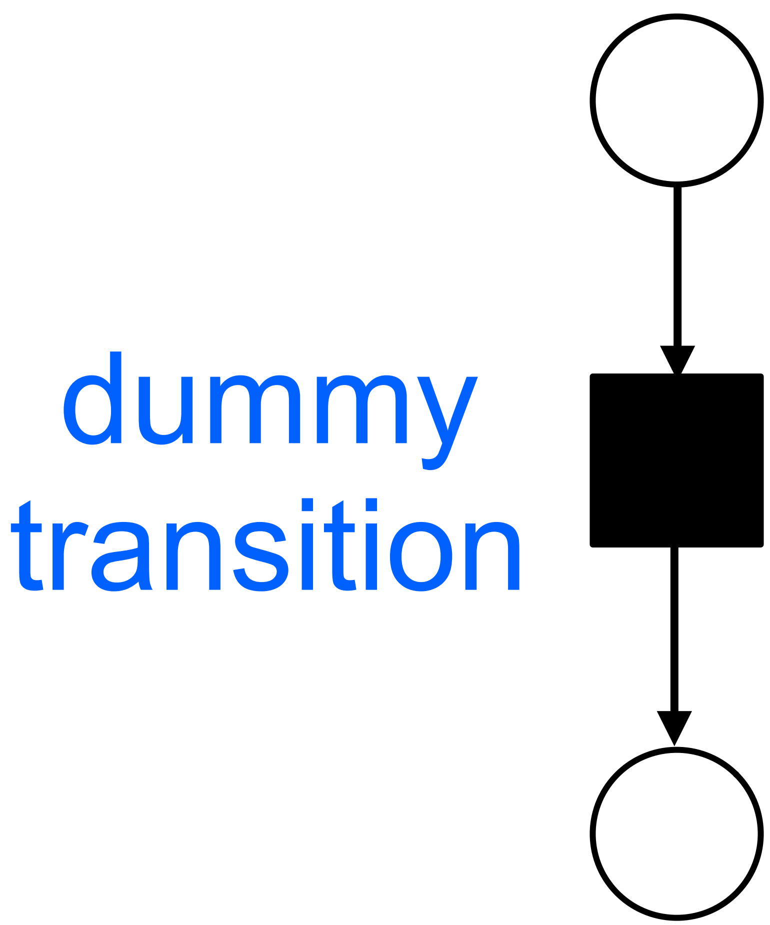
join


∧
XOR
∨
corresp.
split
better to
have a
corresp.
XOR
split
matched
OR split
corresp.
split: wfa
corresp.
split: fc
better to
have a
corresp.
XOR
split
corresp.
split: et

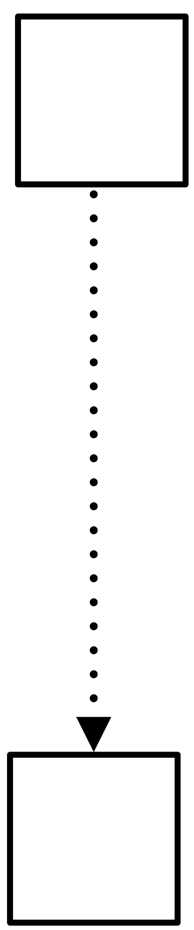
Ill-formed net



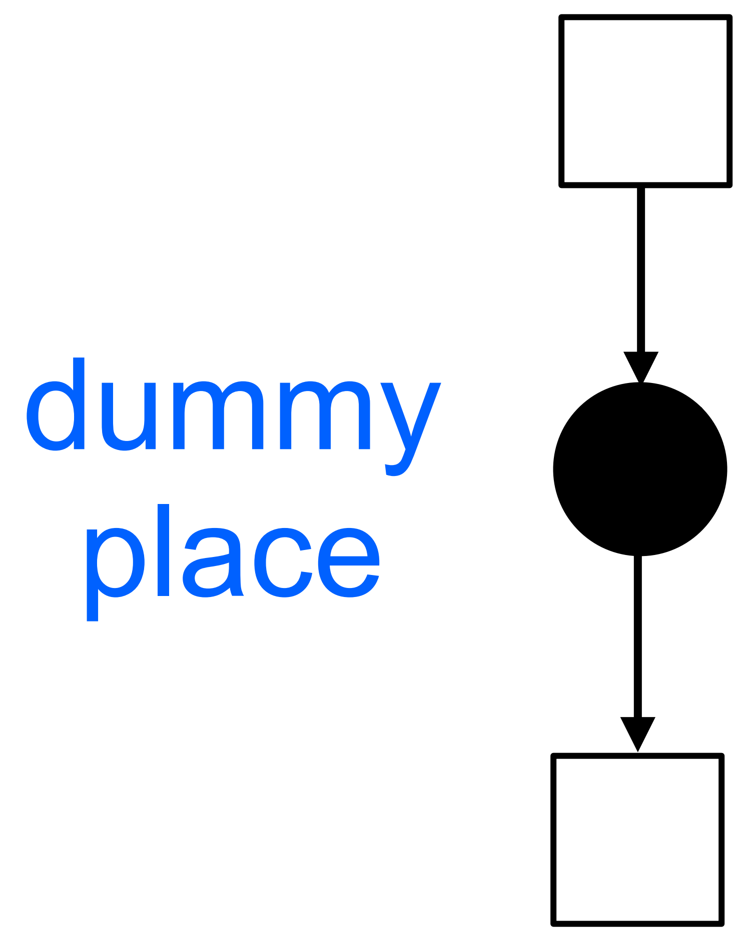
Petri net



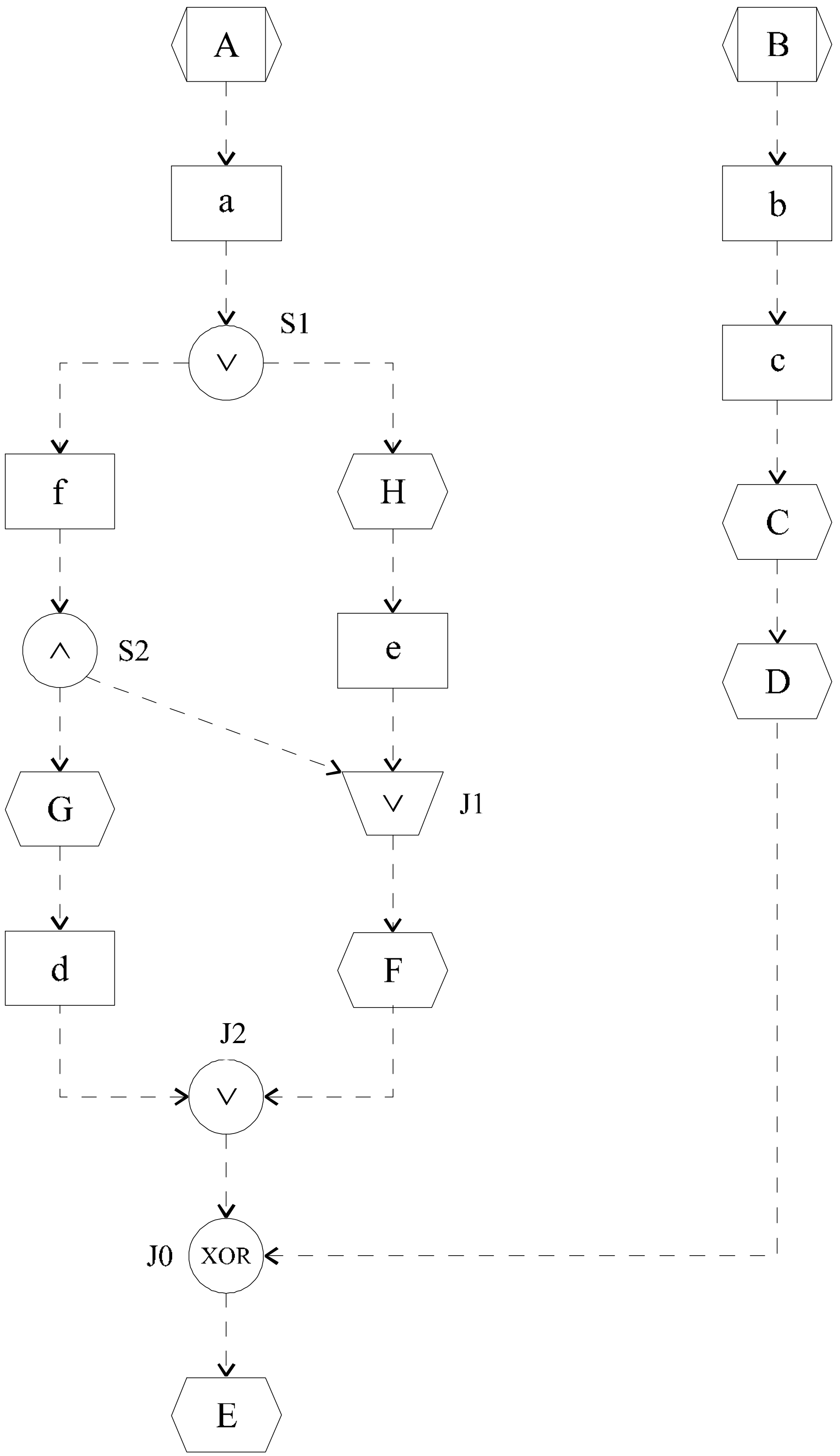
Ill-formed net



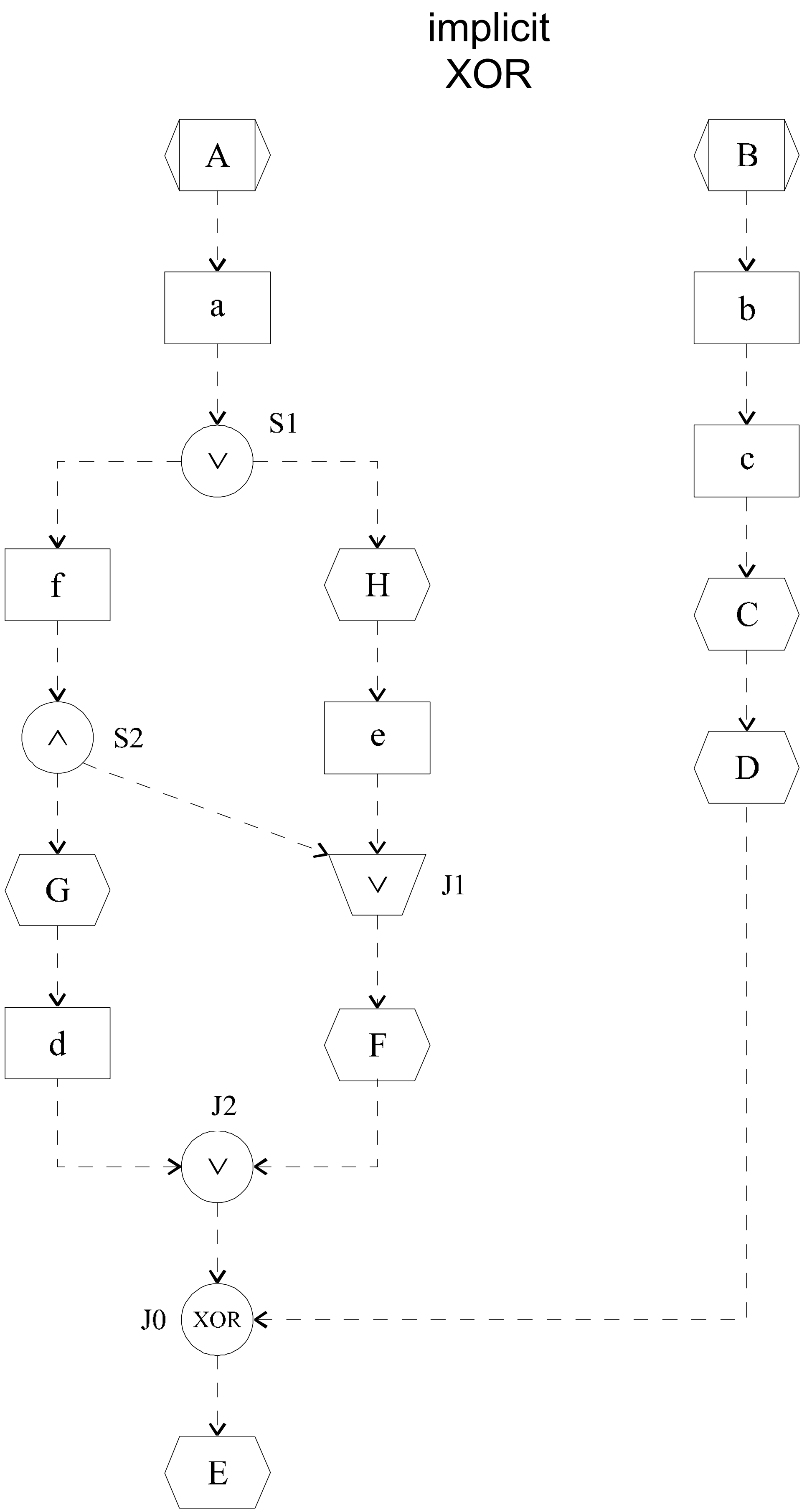
Petri net



Example

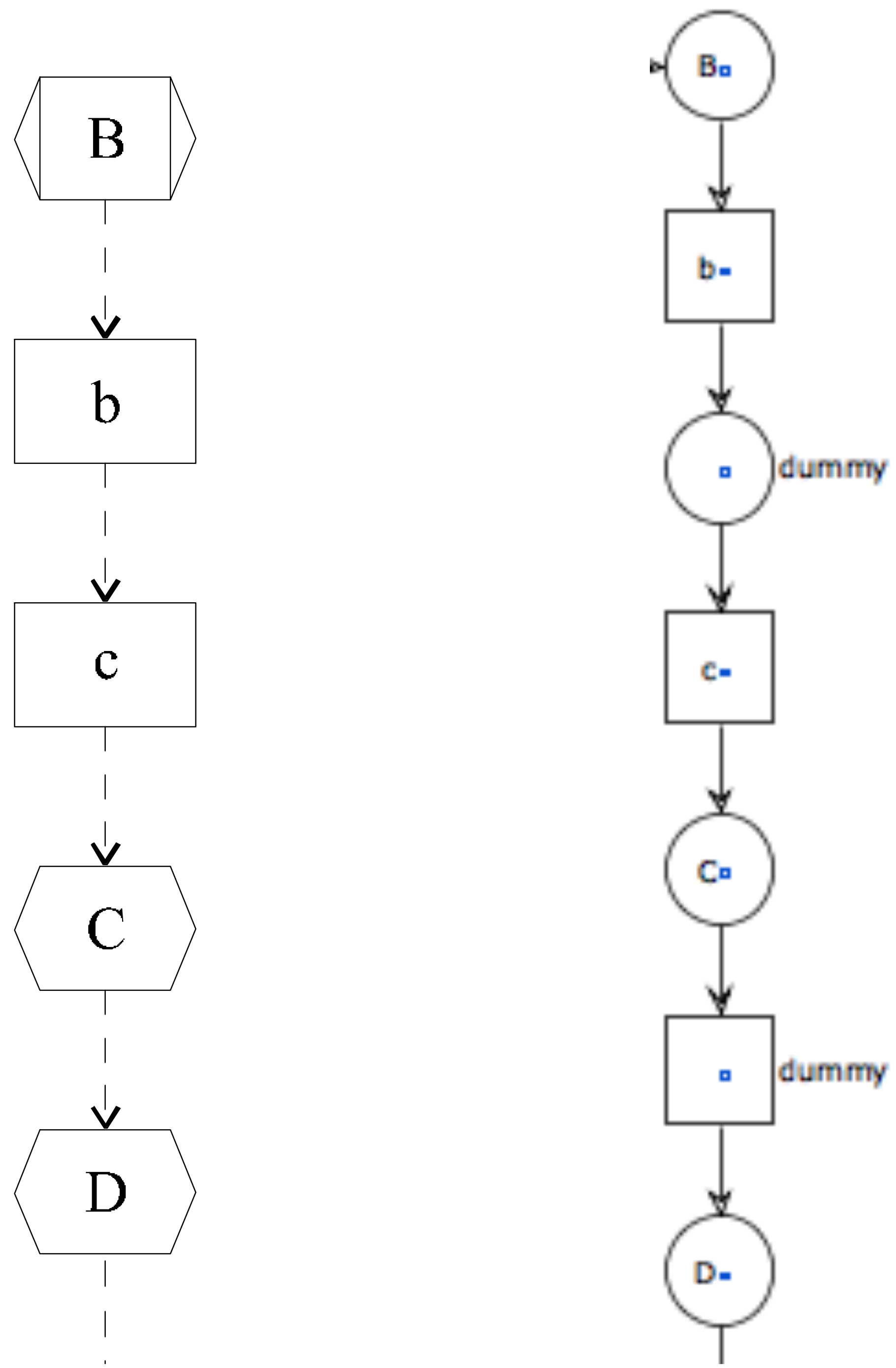


Example

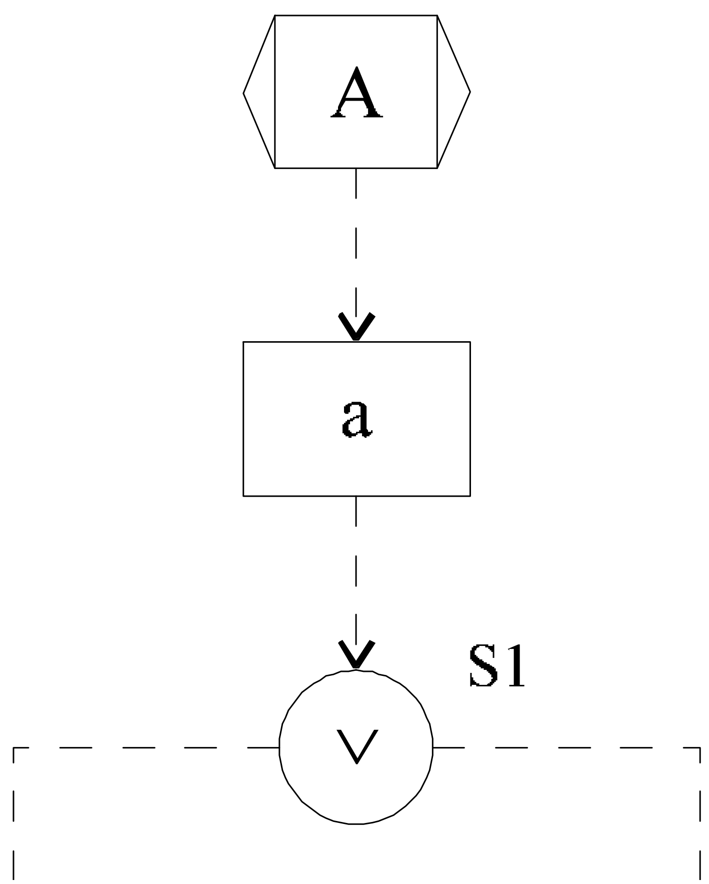


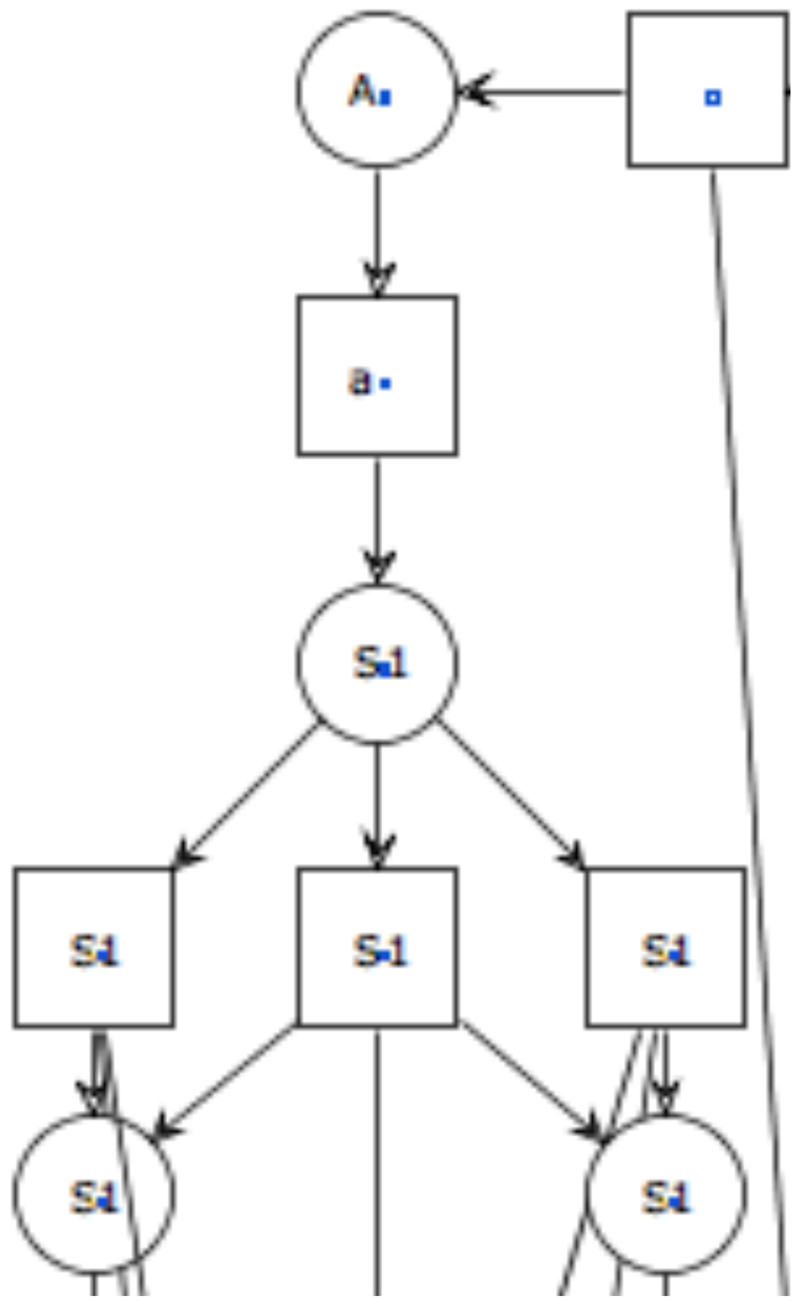
Example

Example

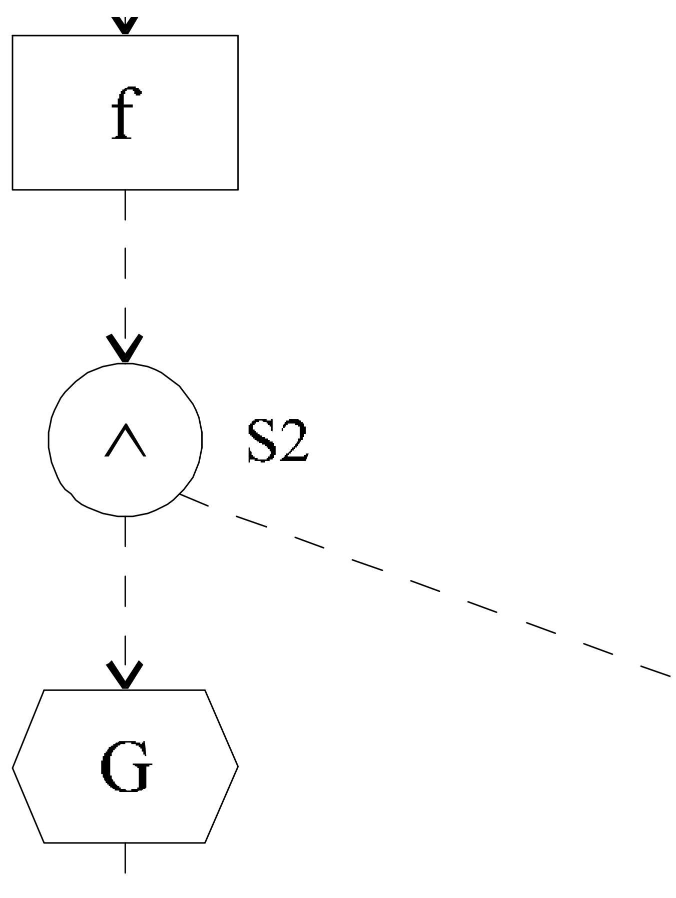


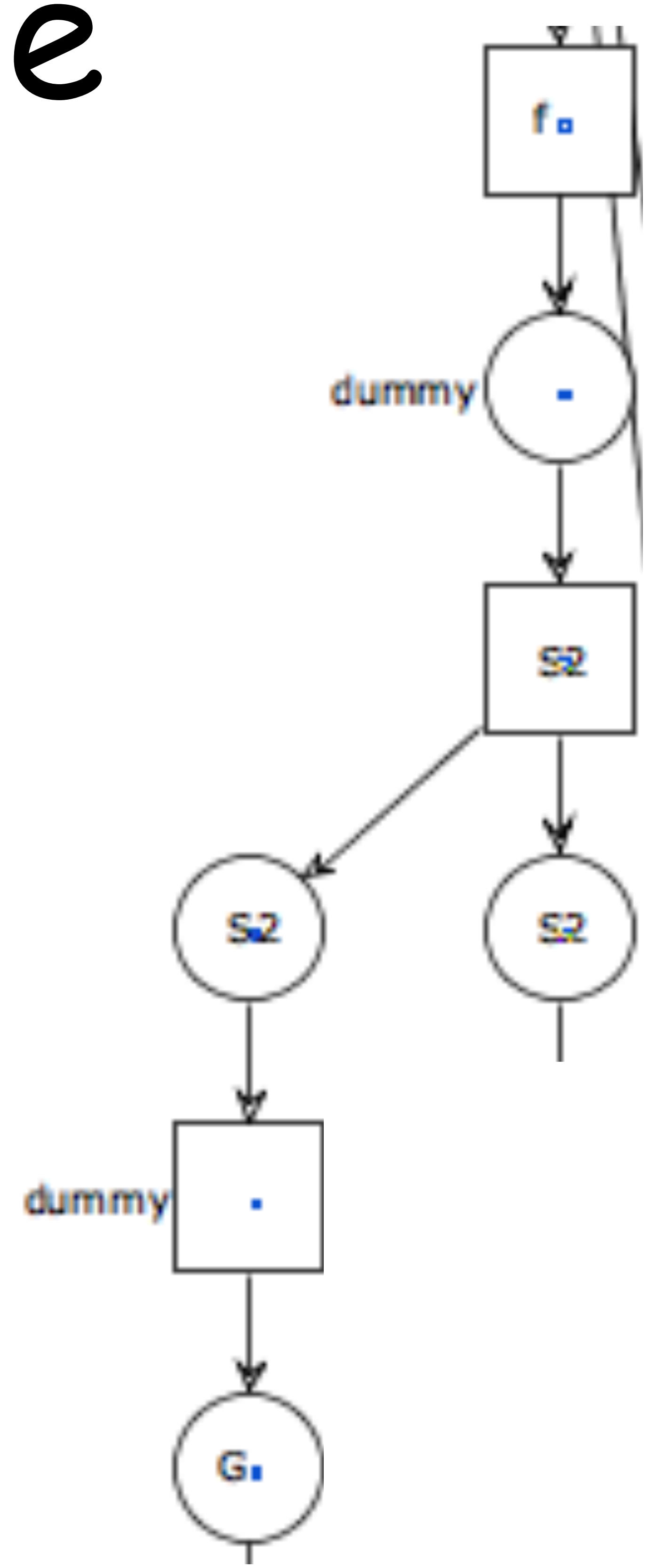
Example



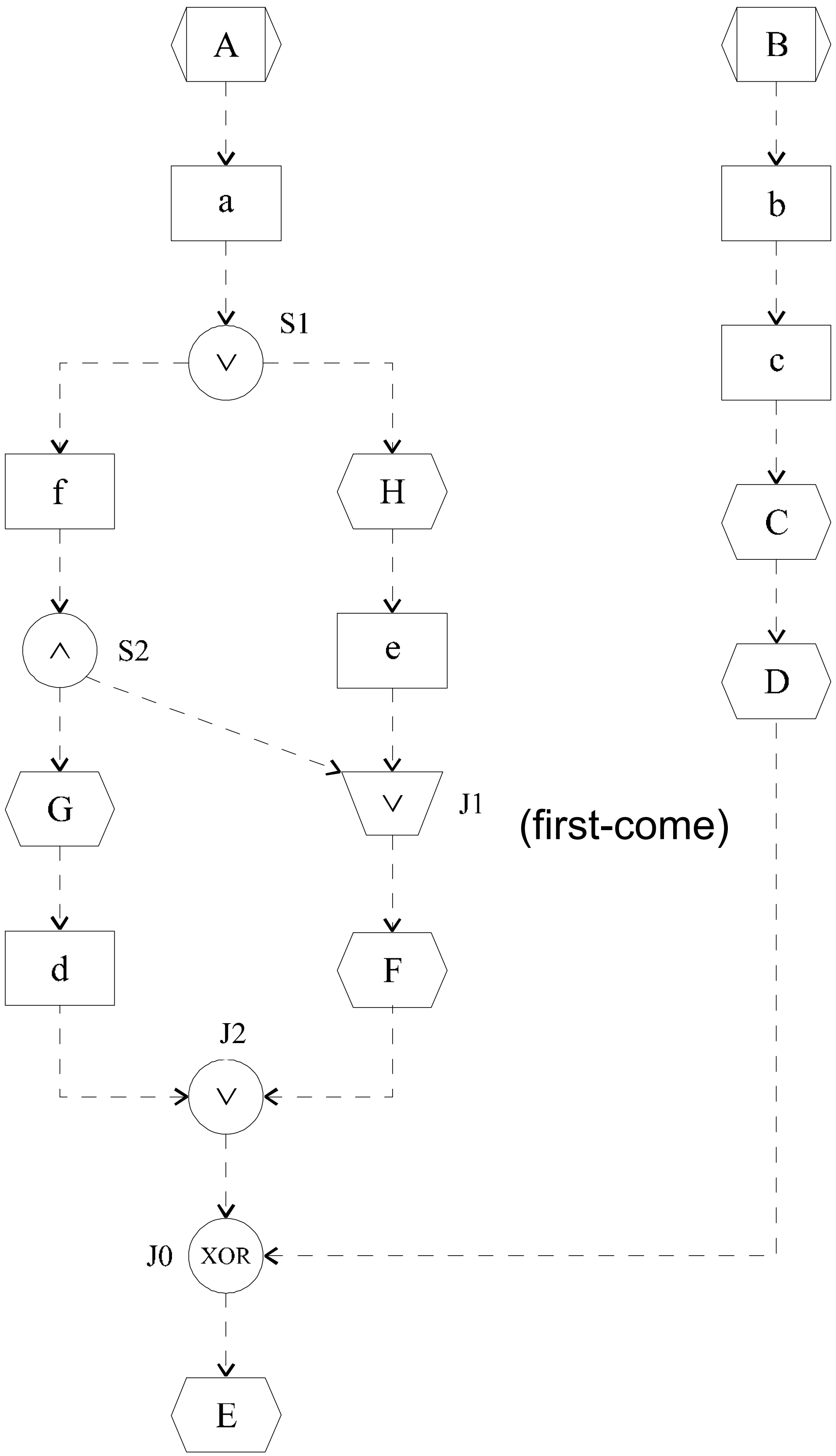


Example



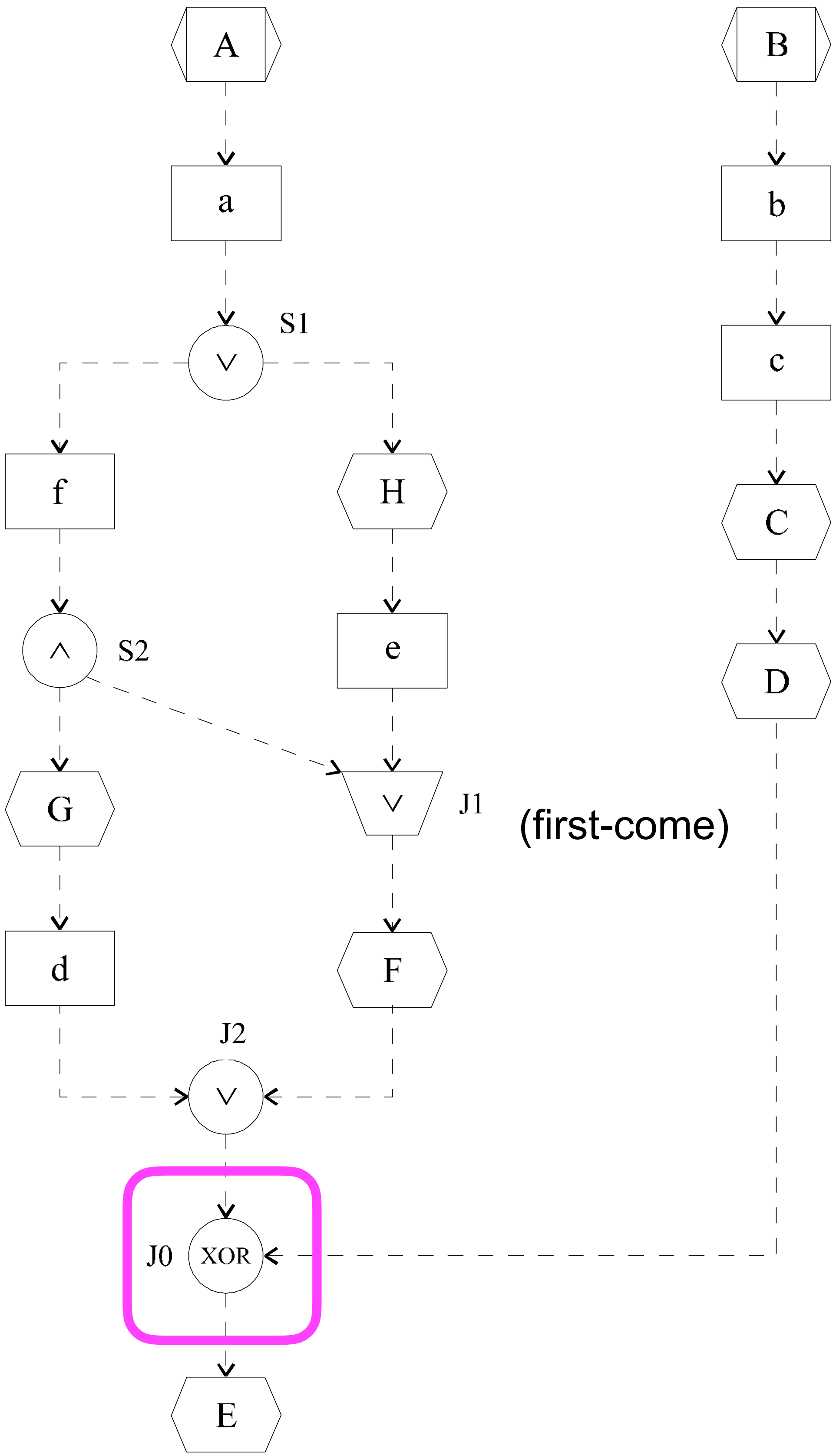


Exercise



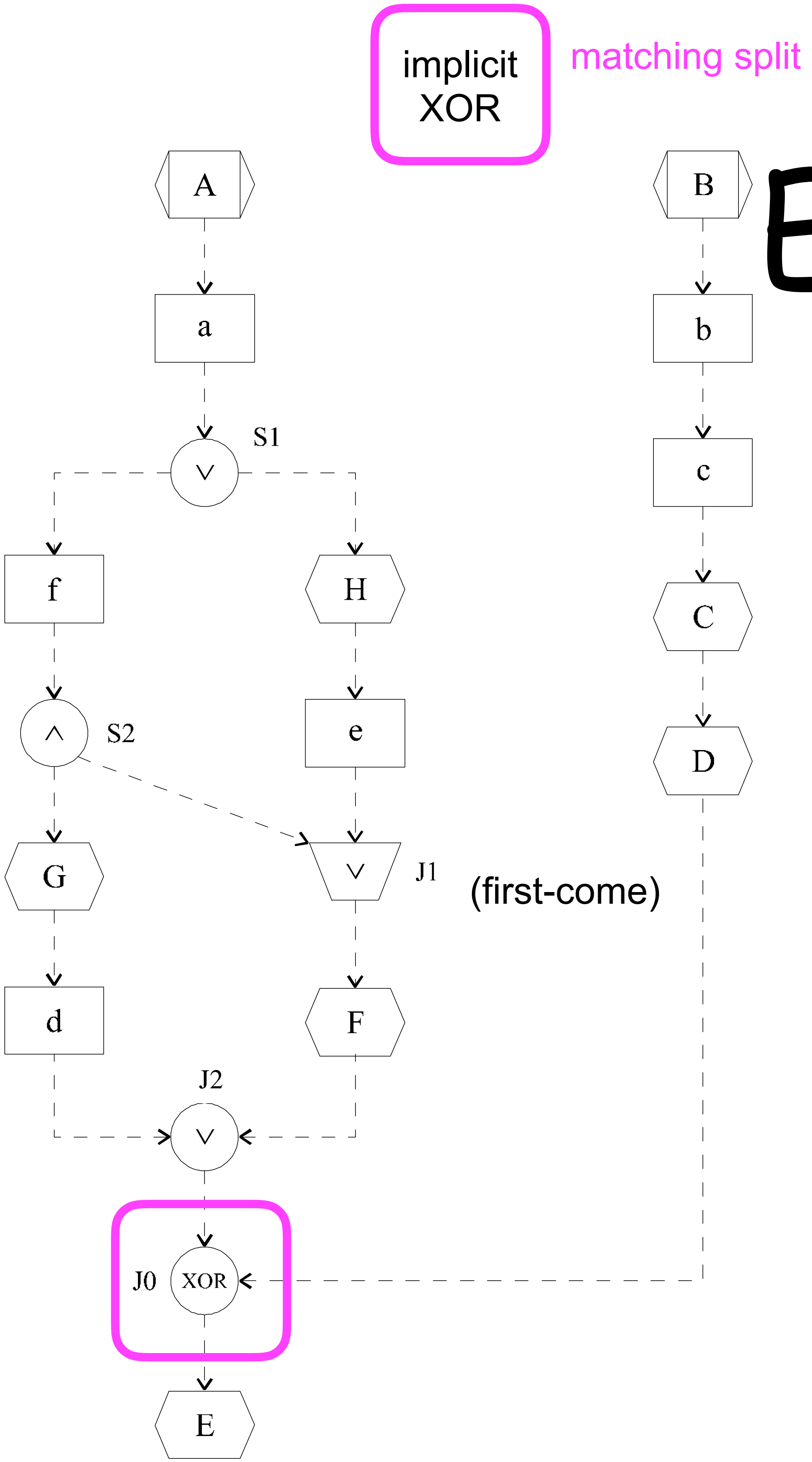
Sound?

Exercise



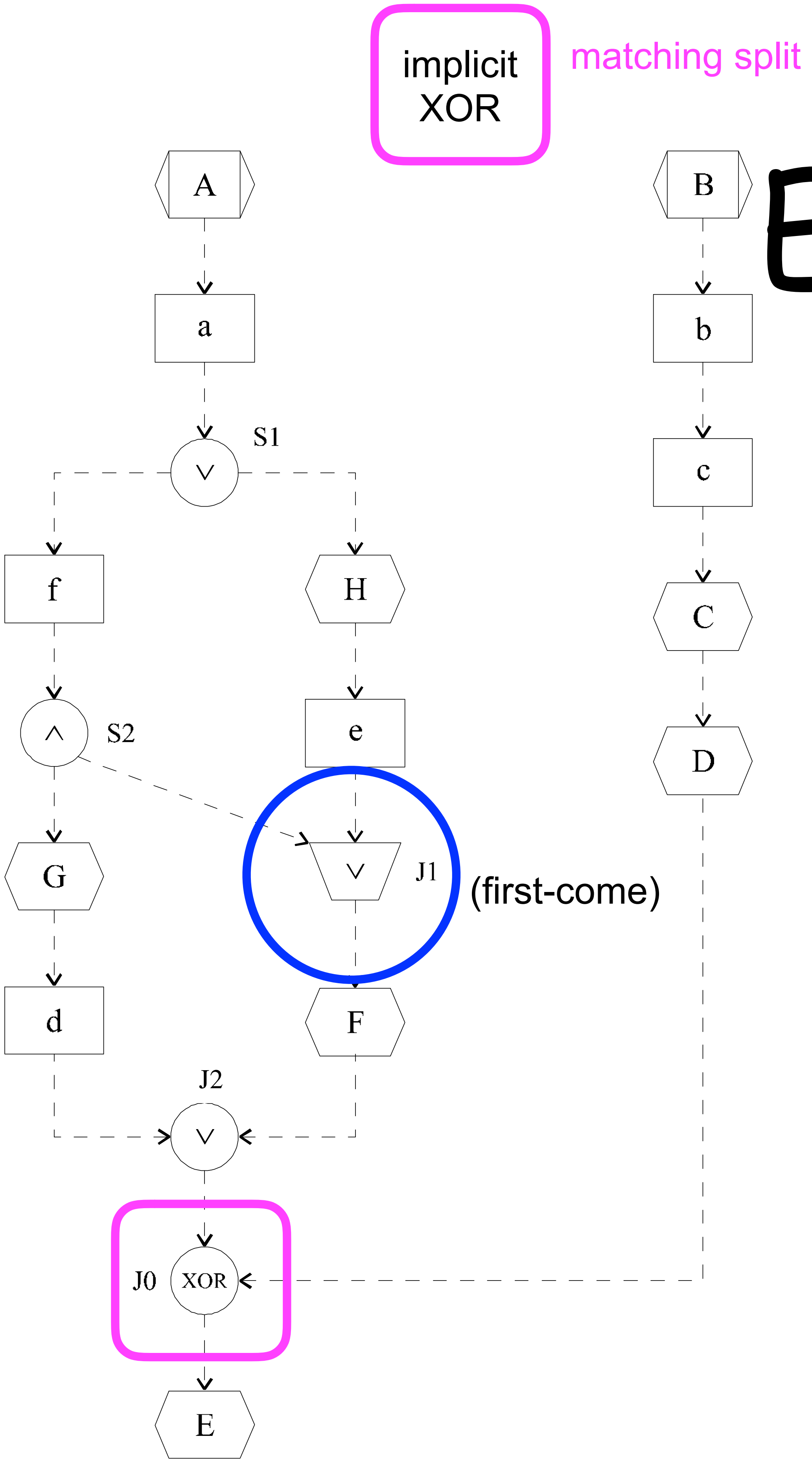
Sound?

Exercise



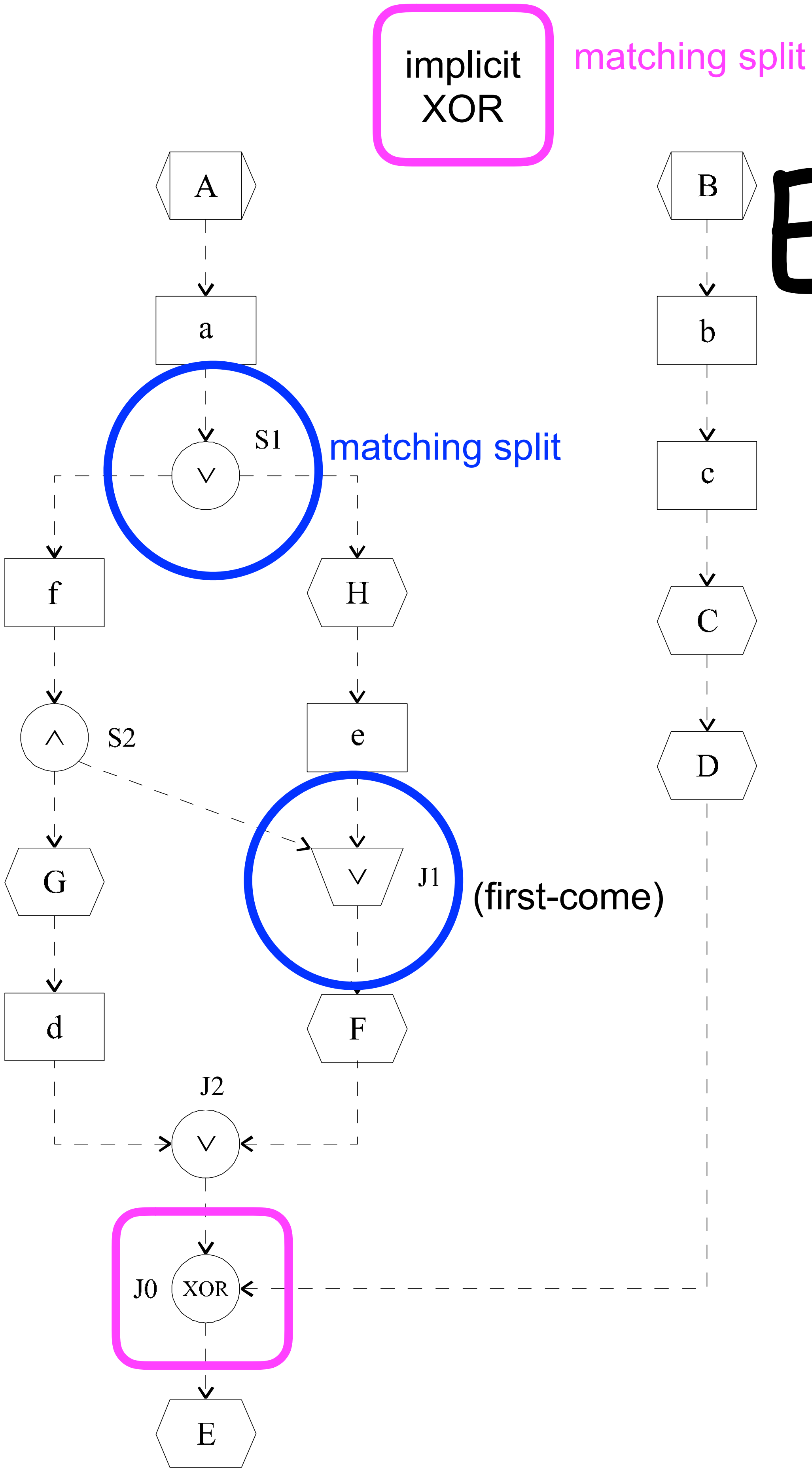
Sound?

Exercise



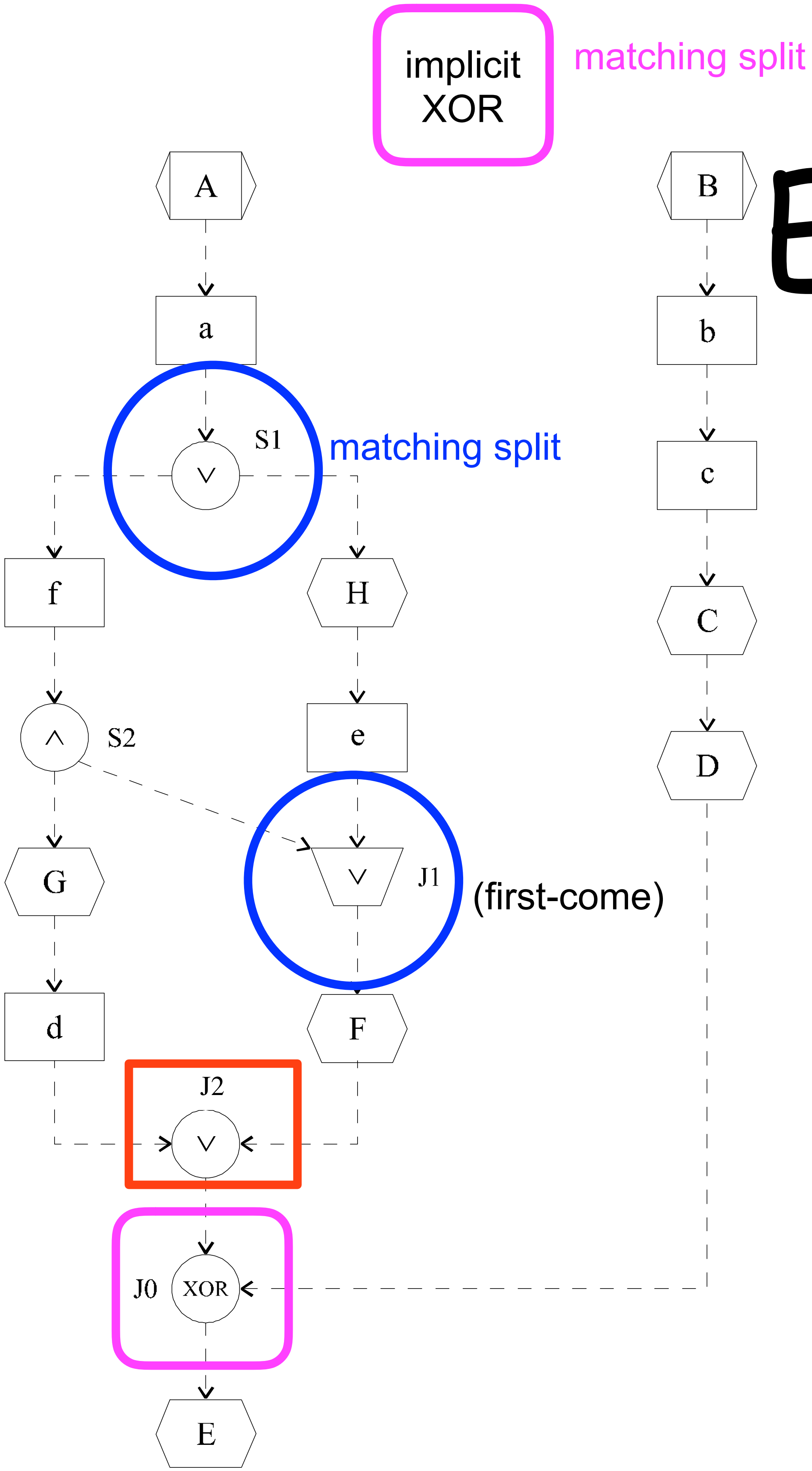
Sound?

Exercise



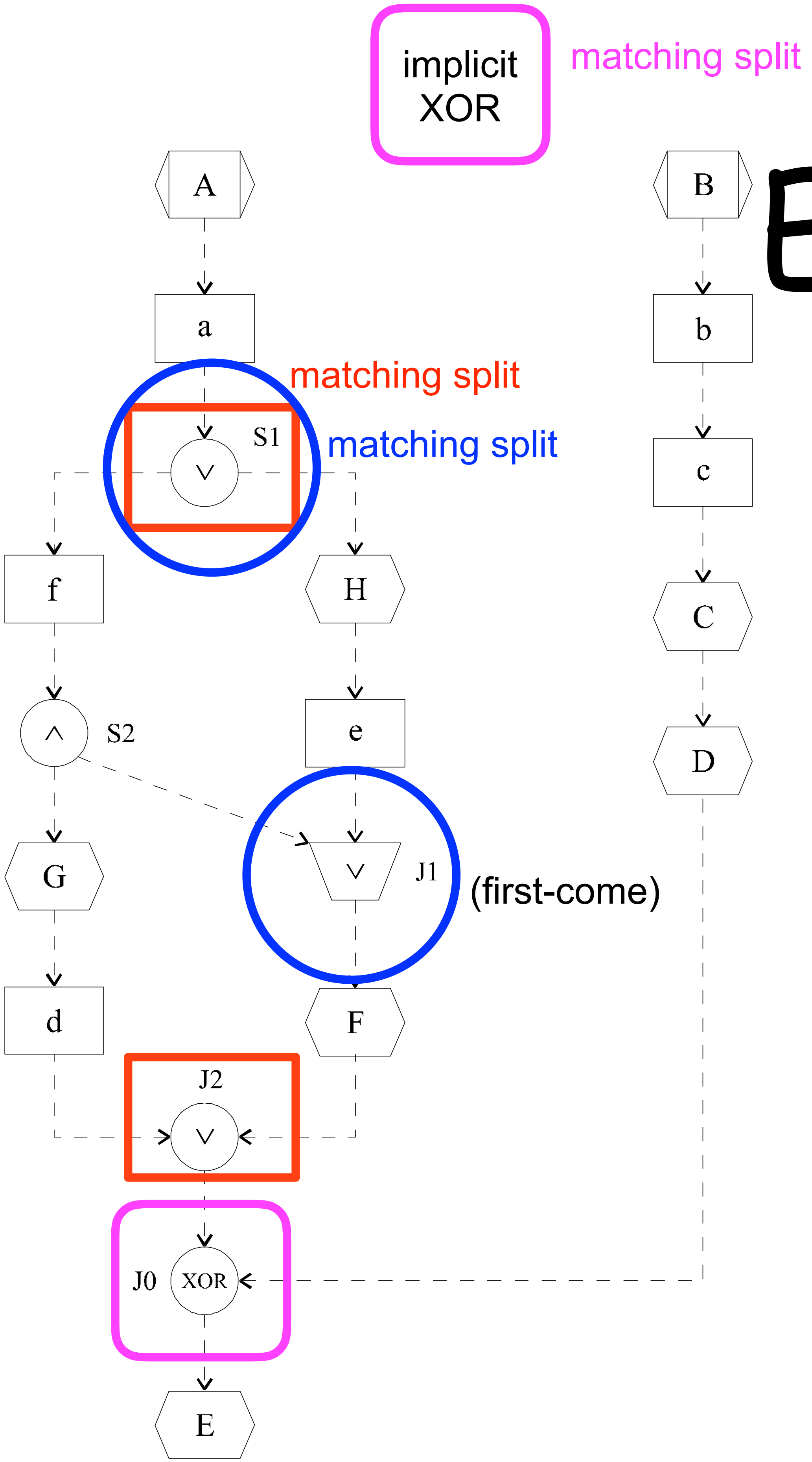
Sound?

Exercise

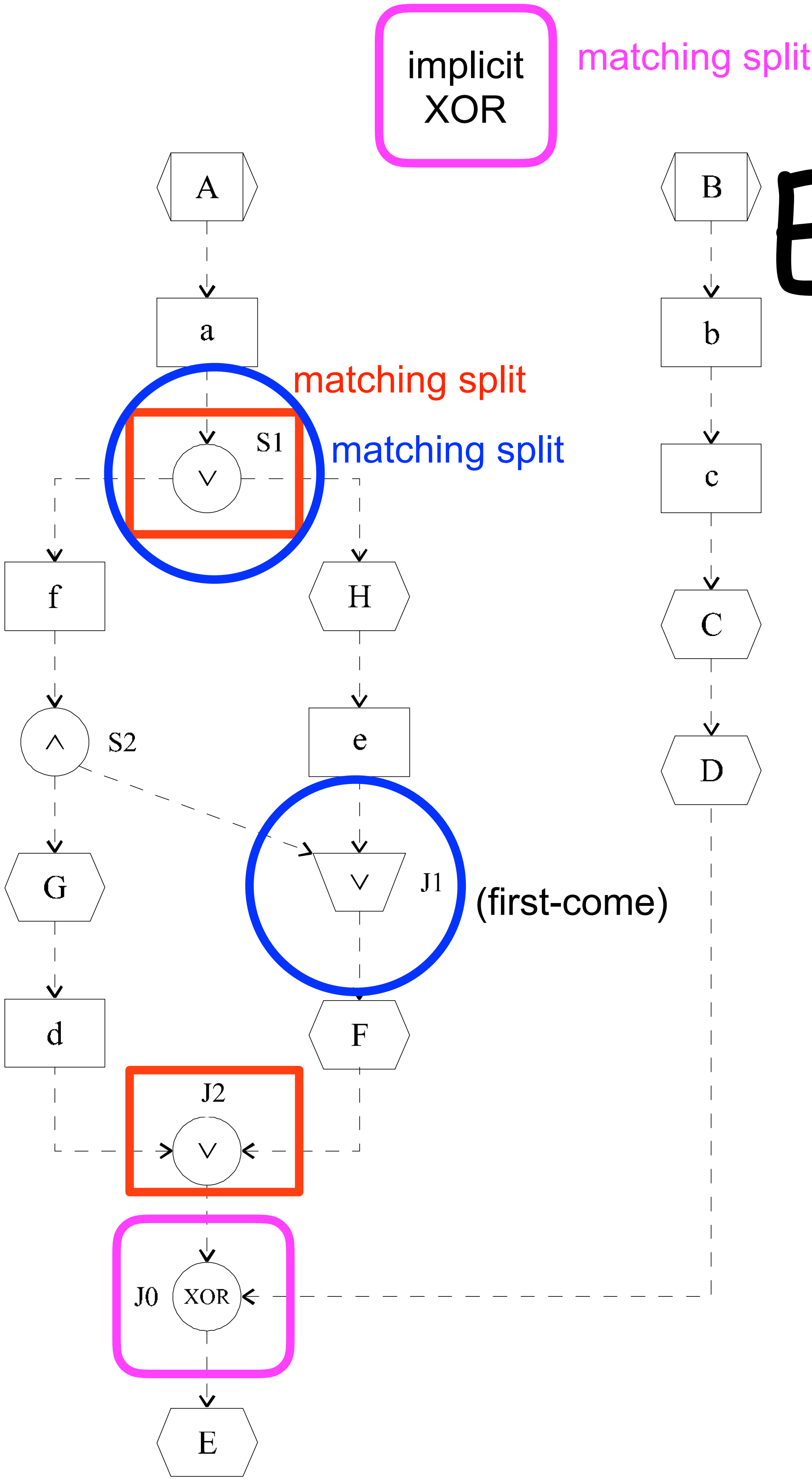


Sound?

Exercise

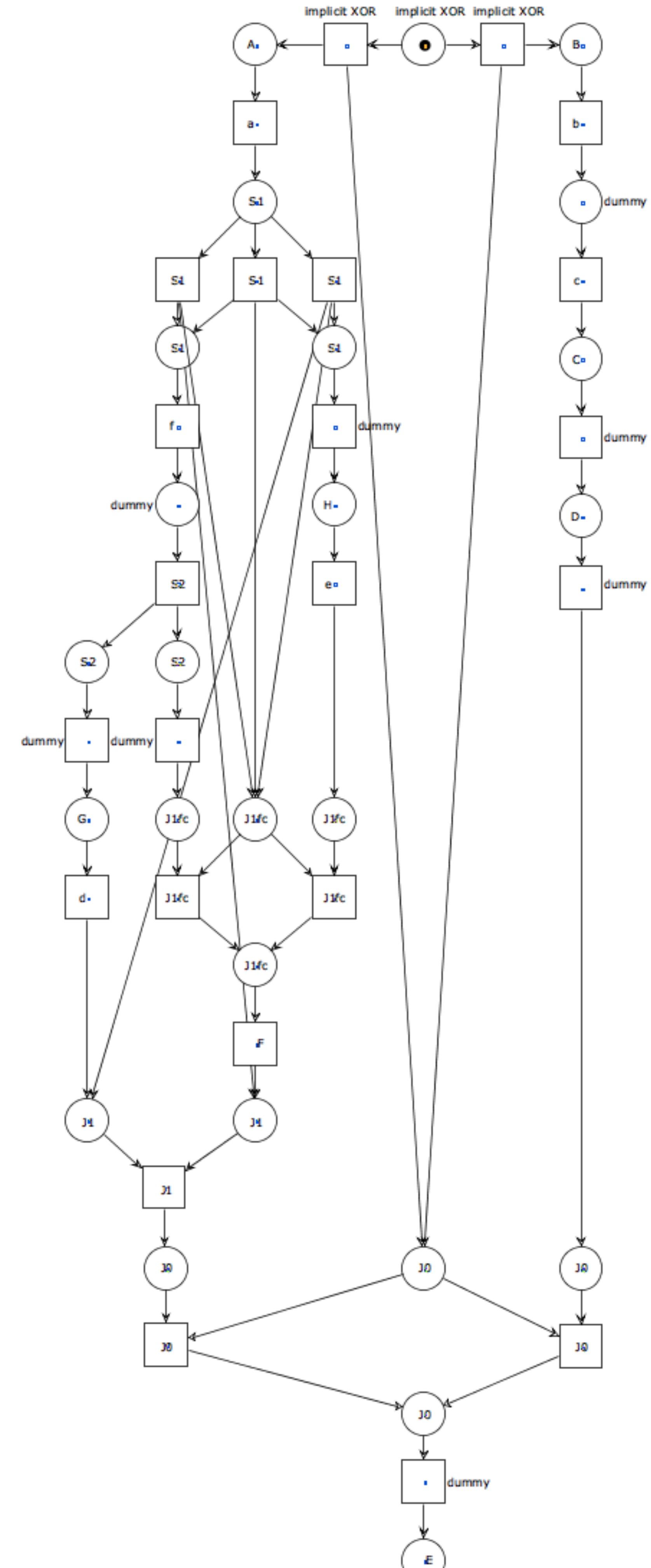


Sound?

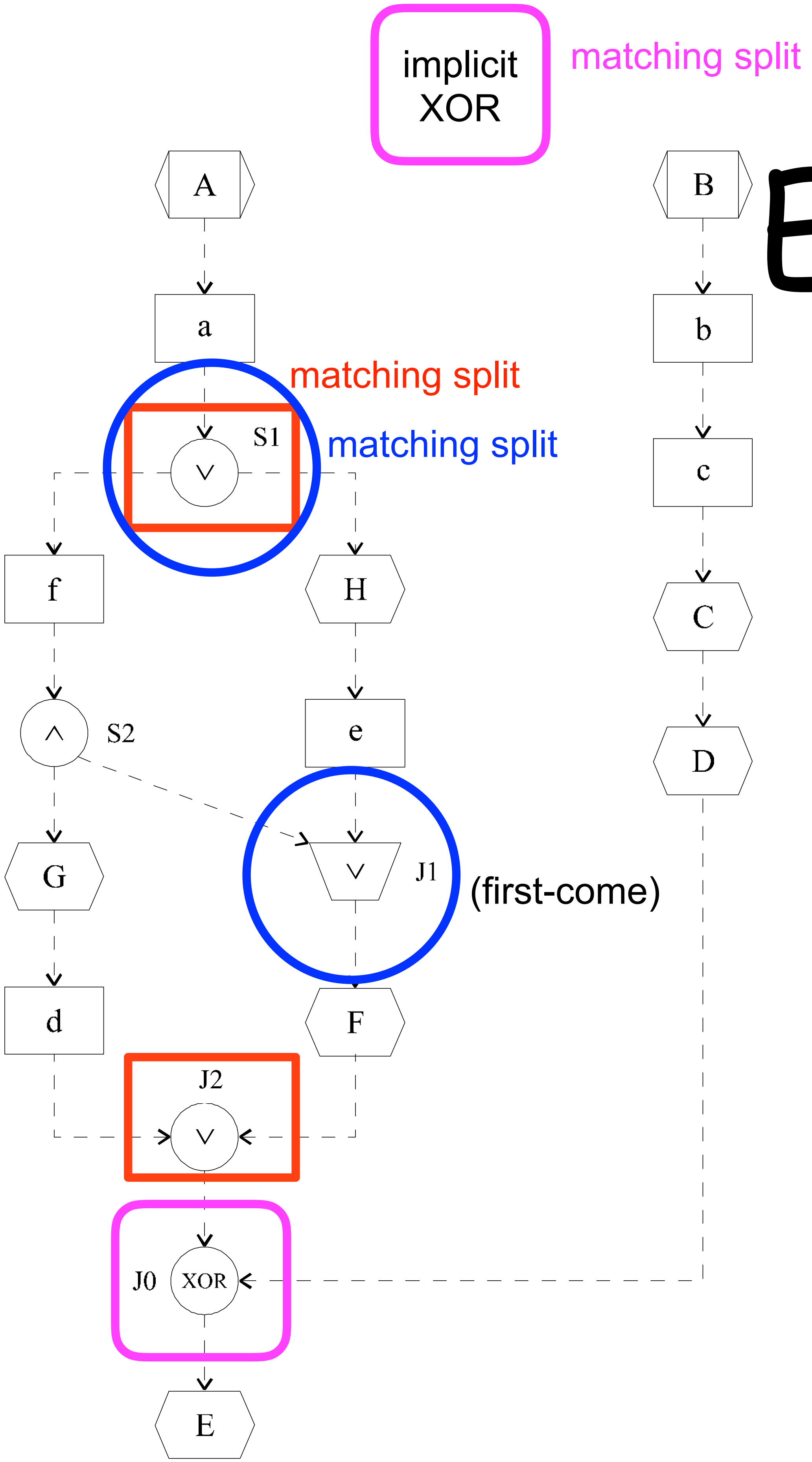


Exercise

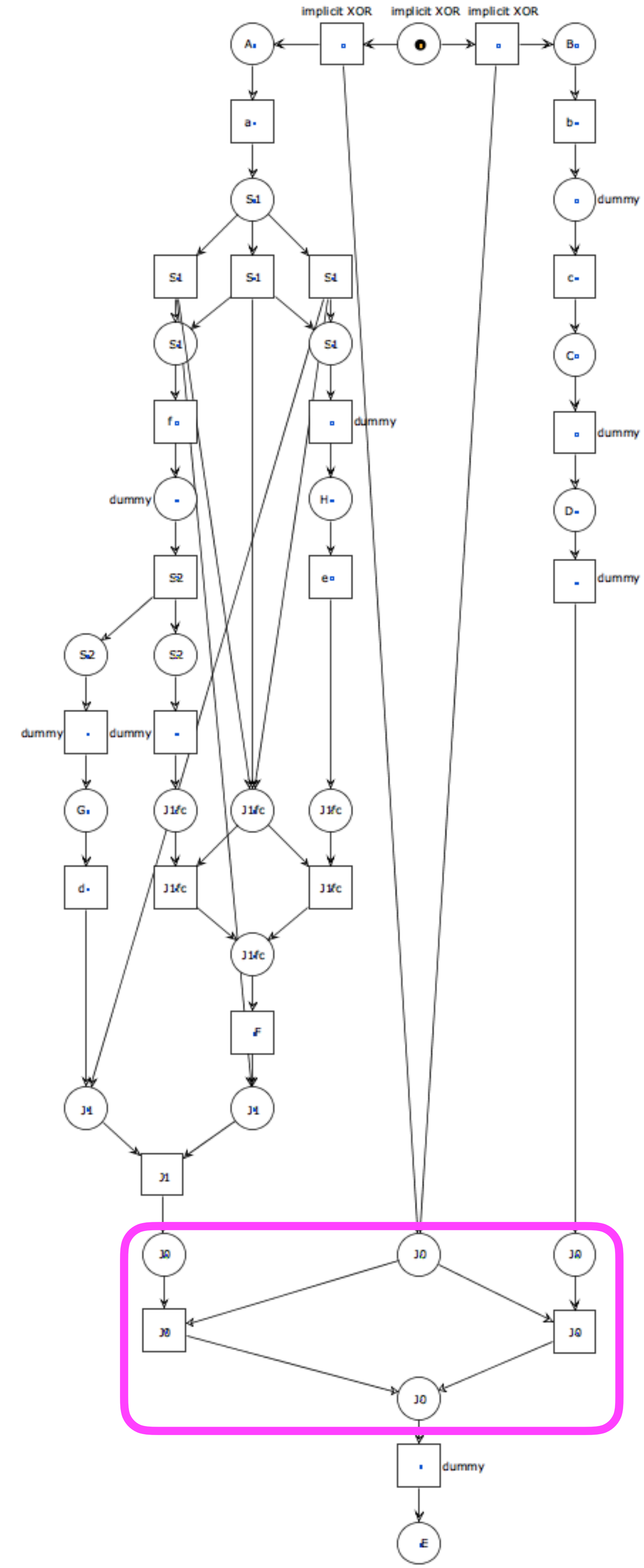
Sound?



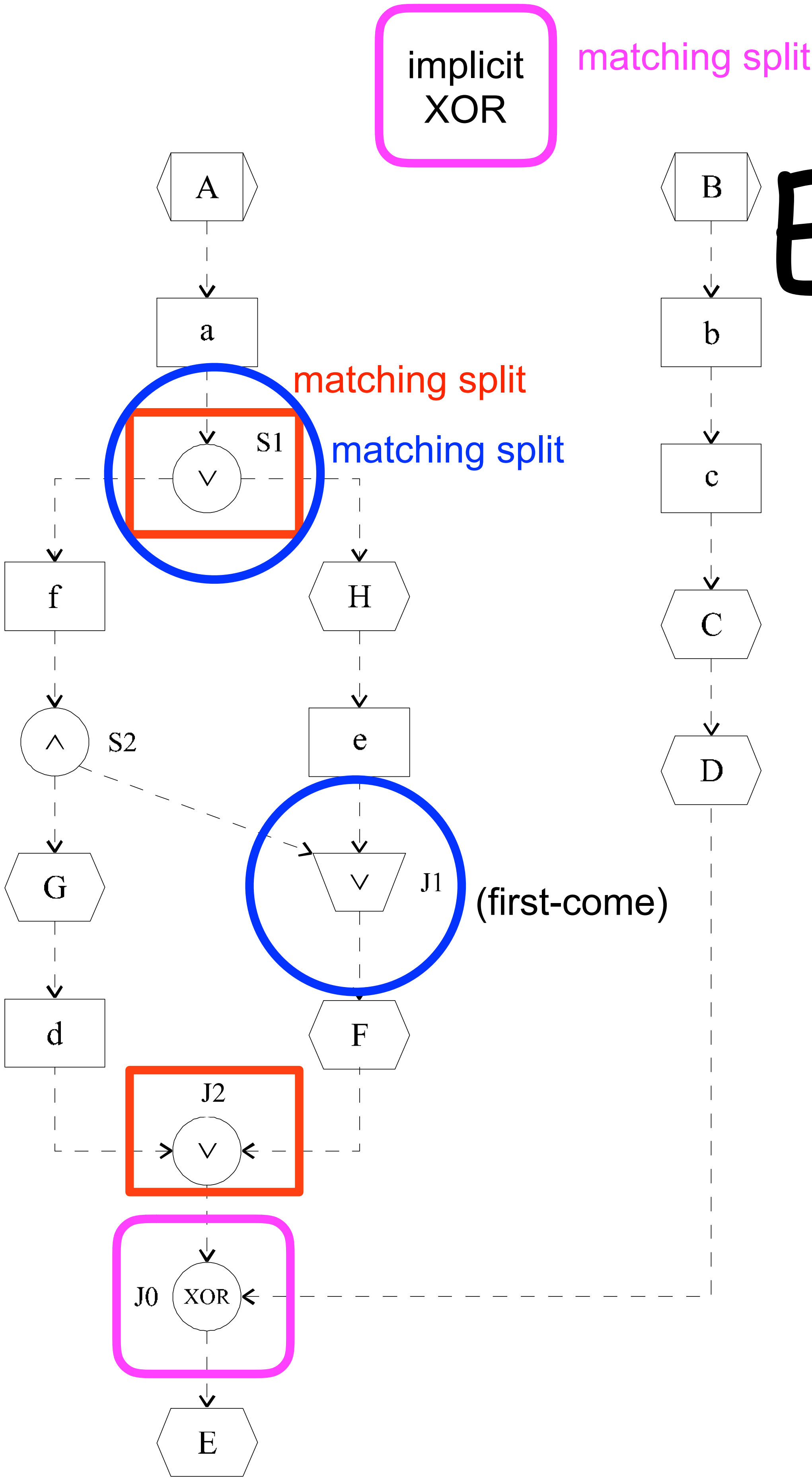
Exercise



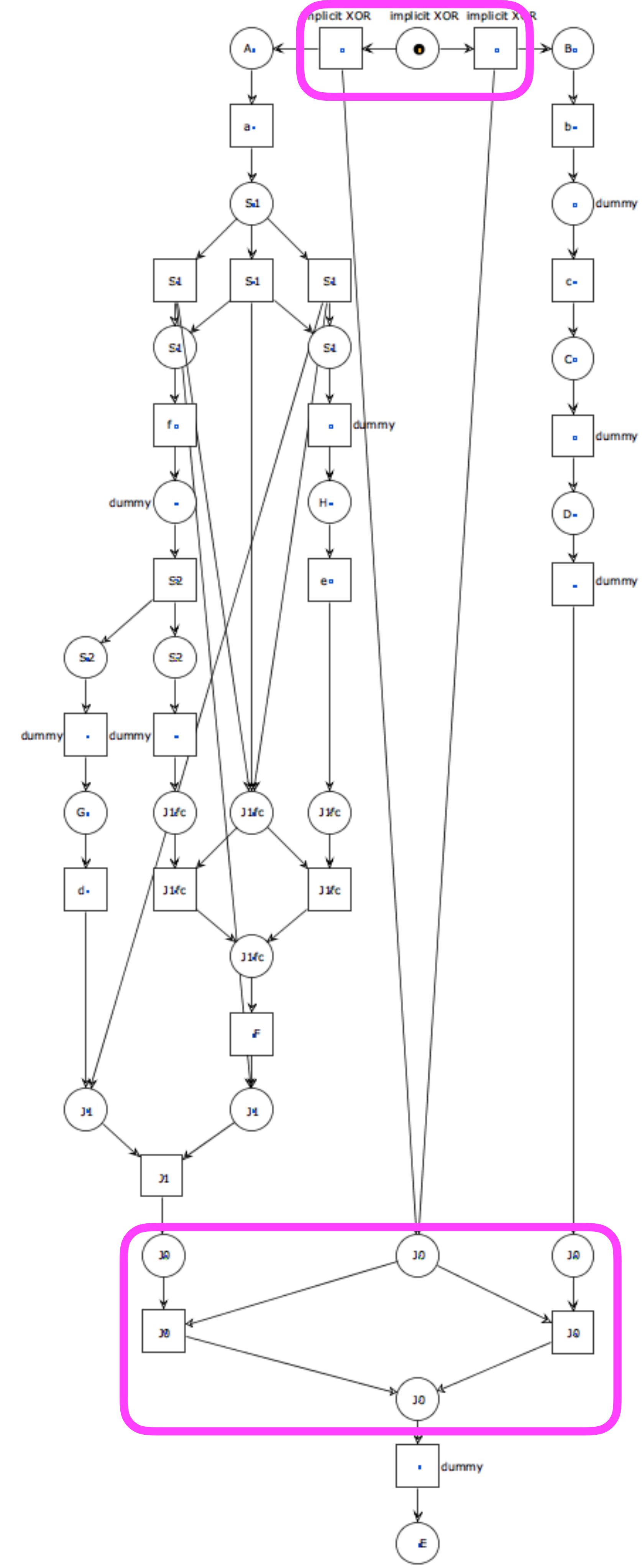
Sound?



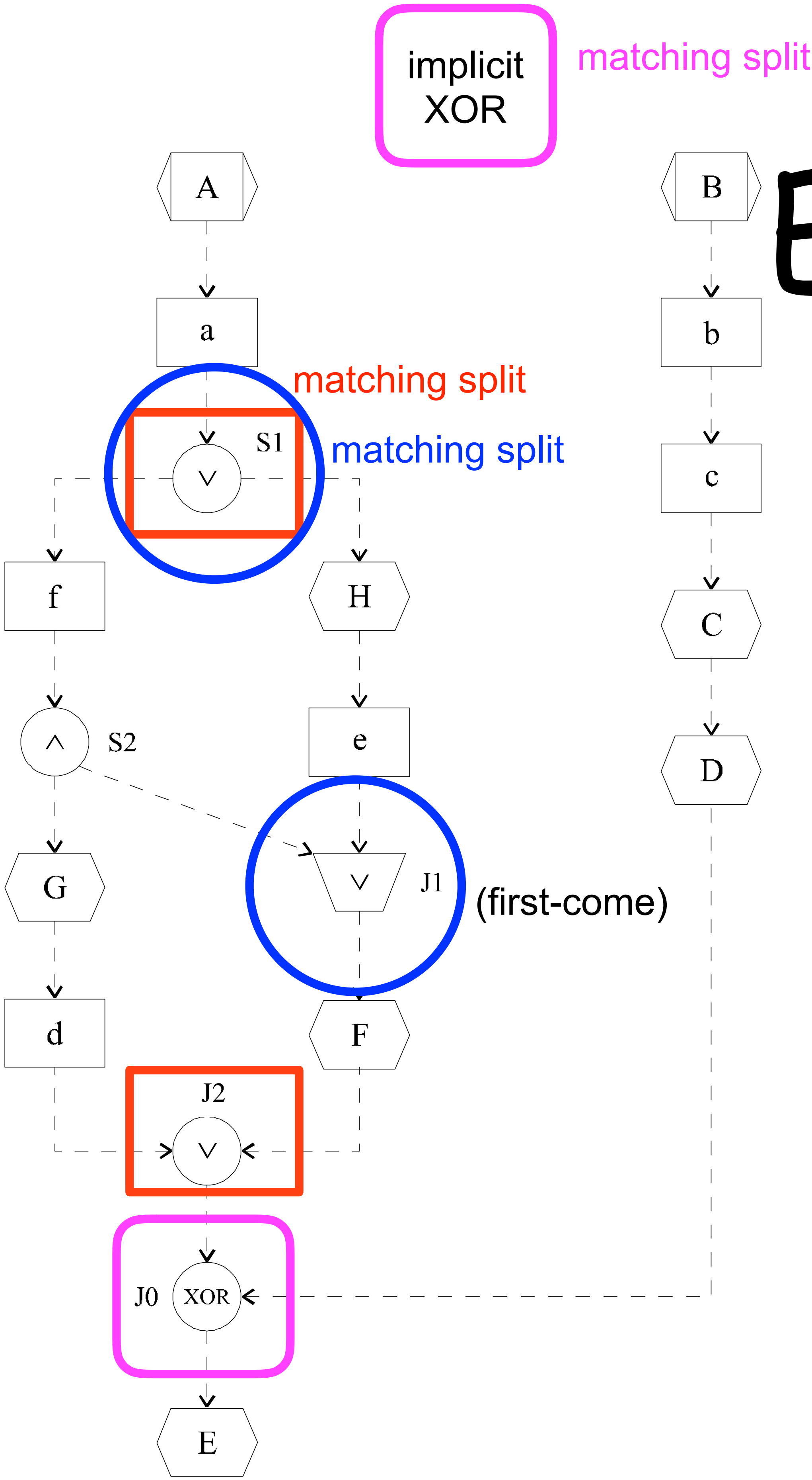
Exercise



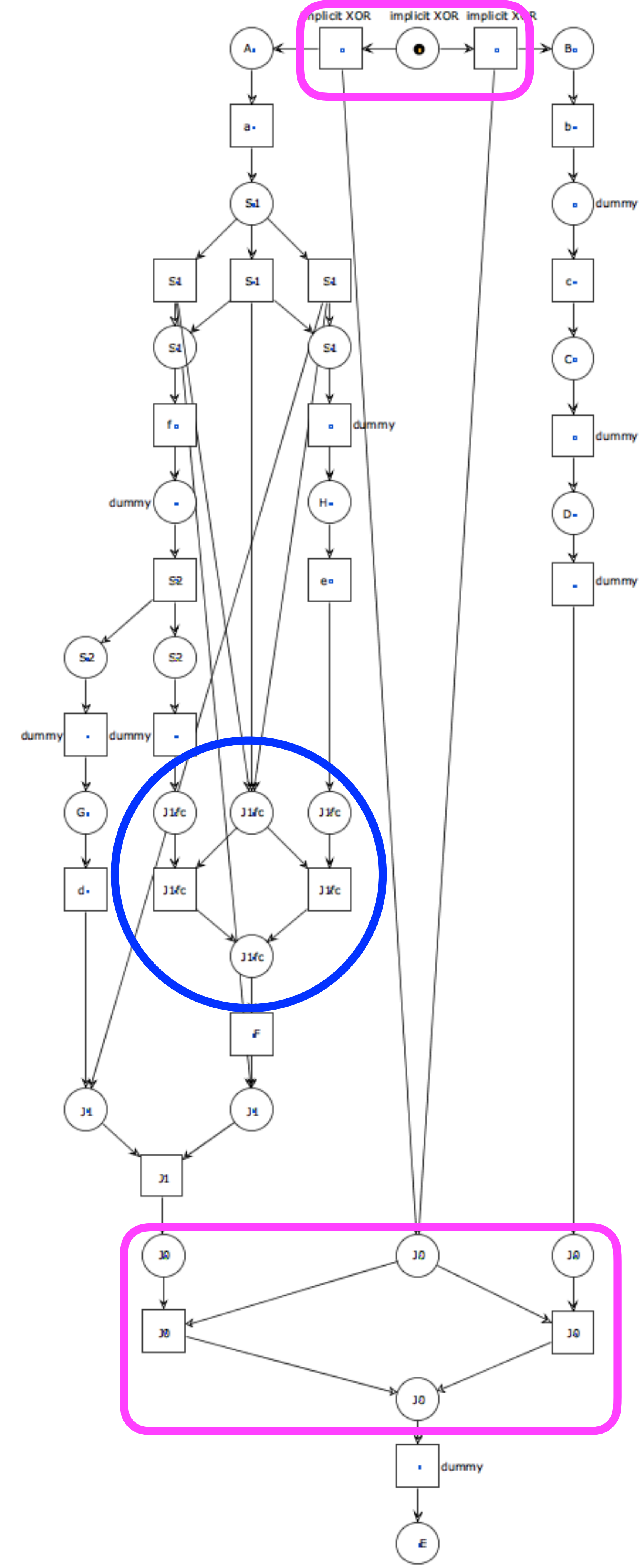
Sound?

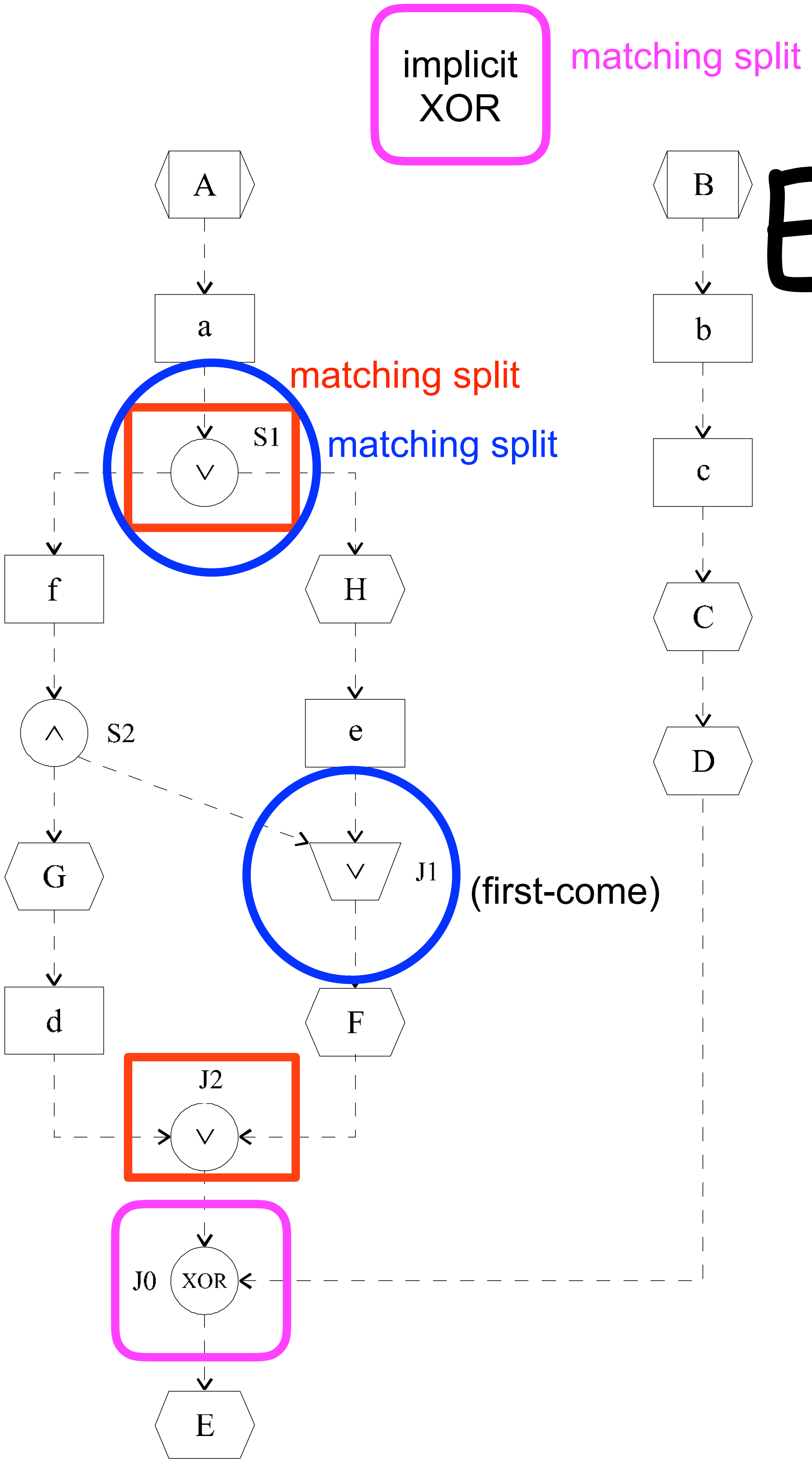


Exercise

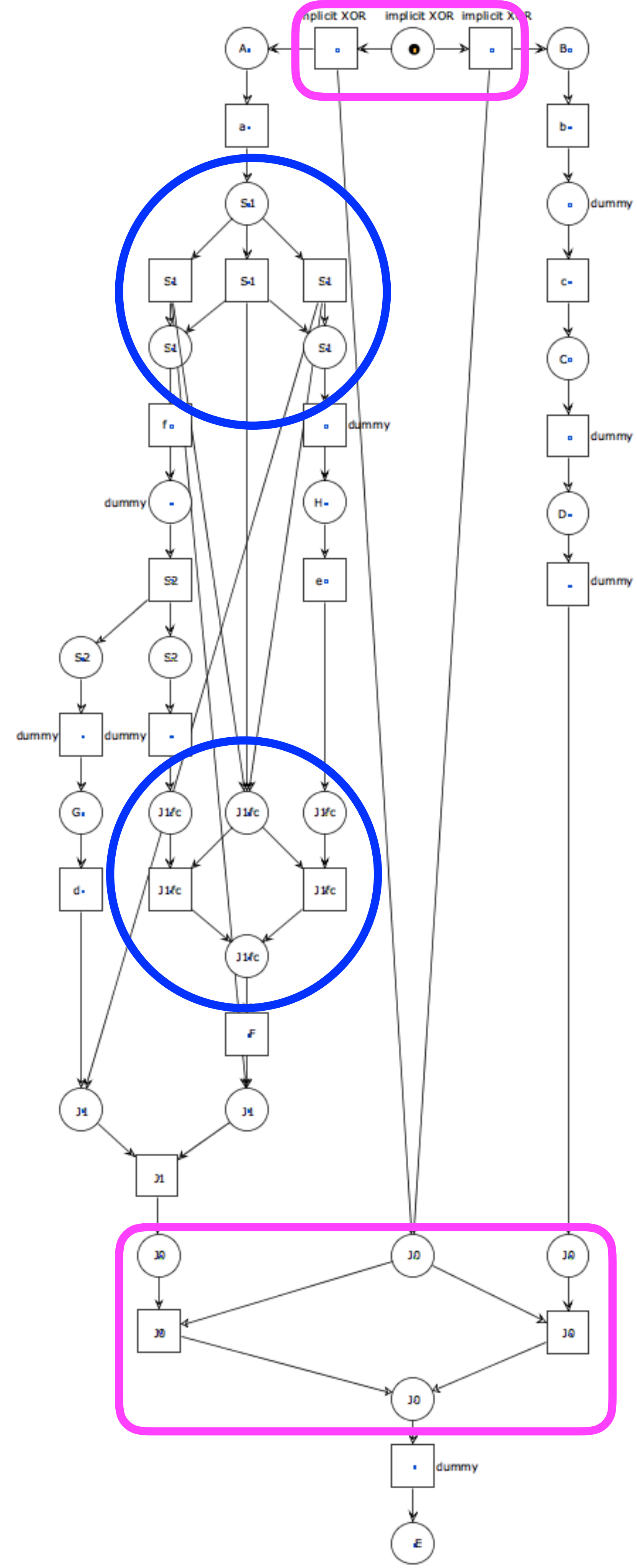


Sound?

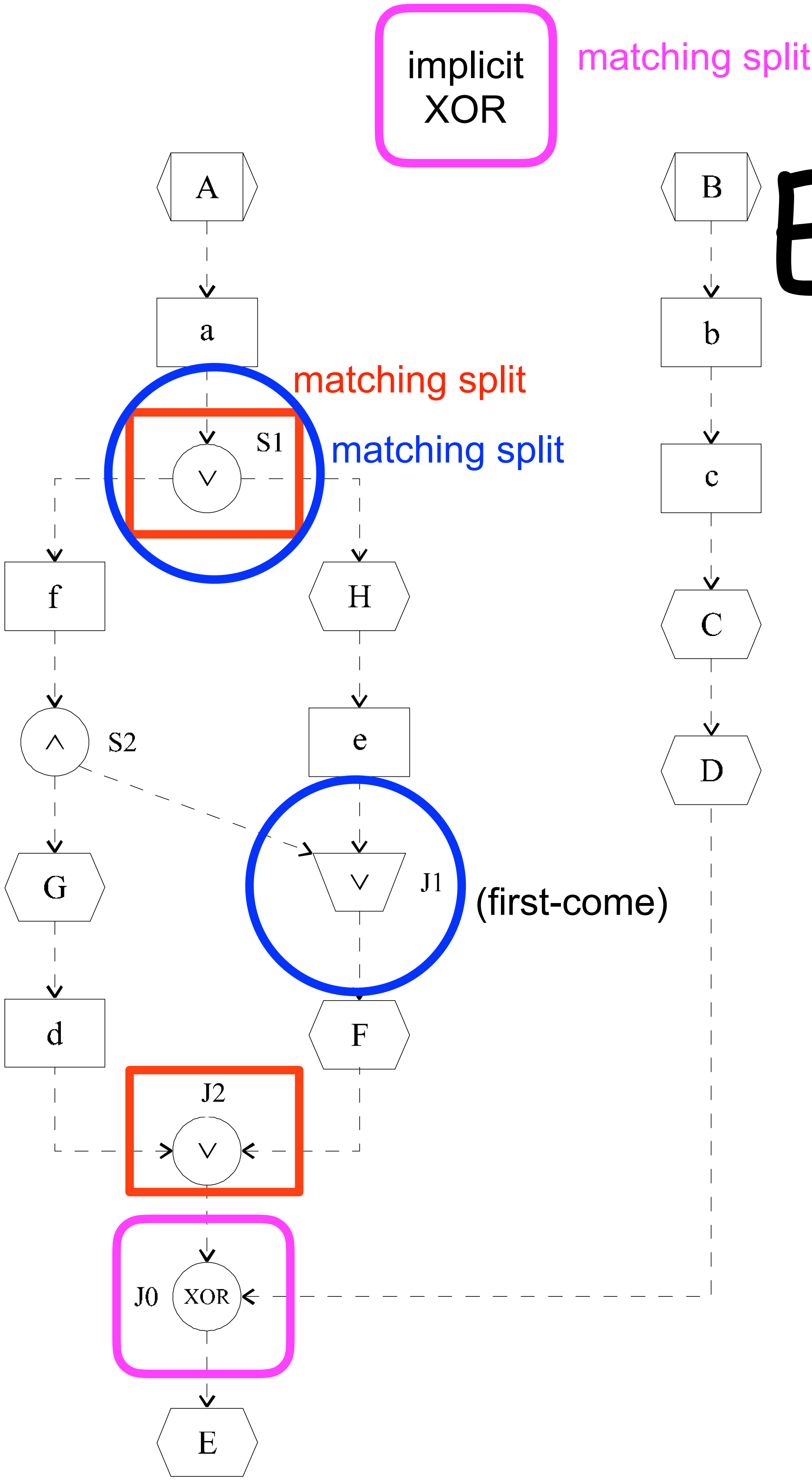




Exercise

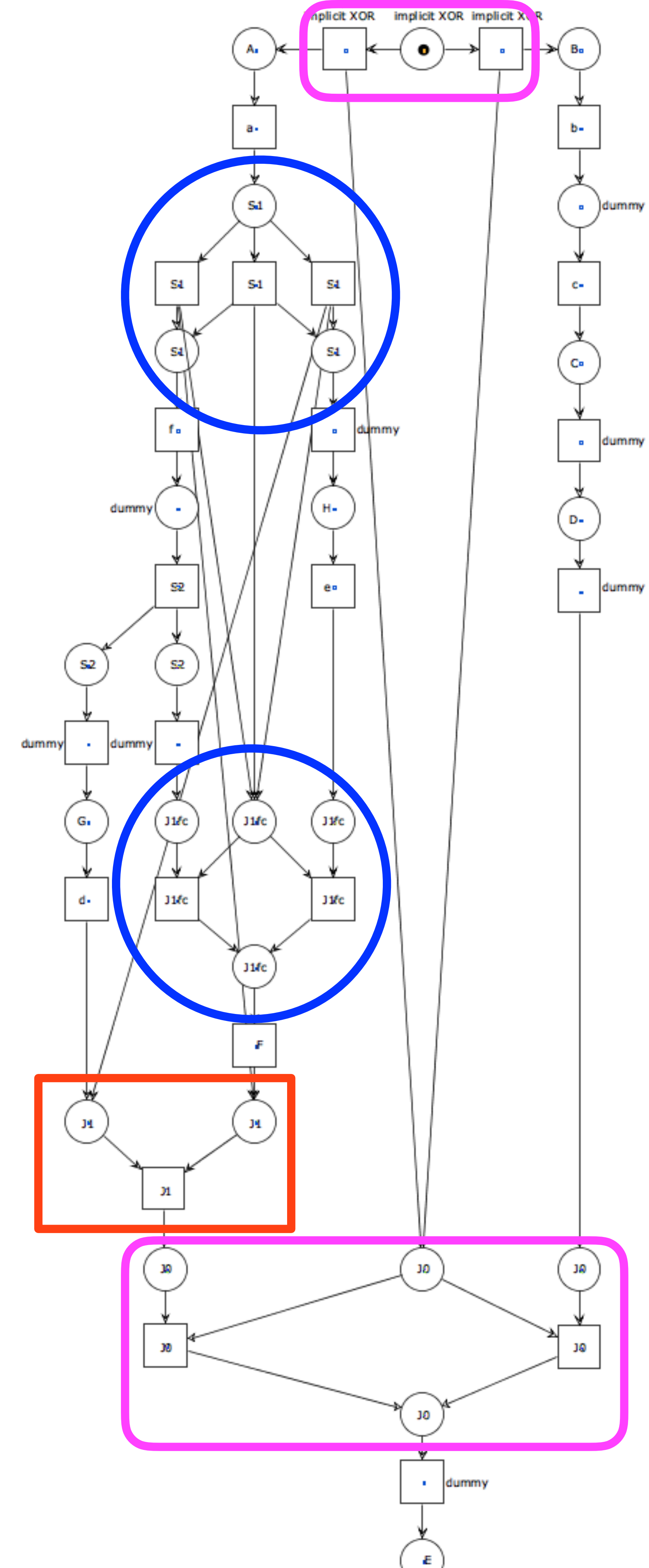


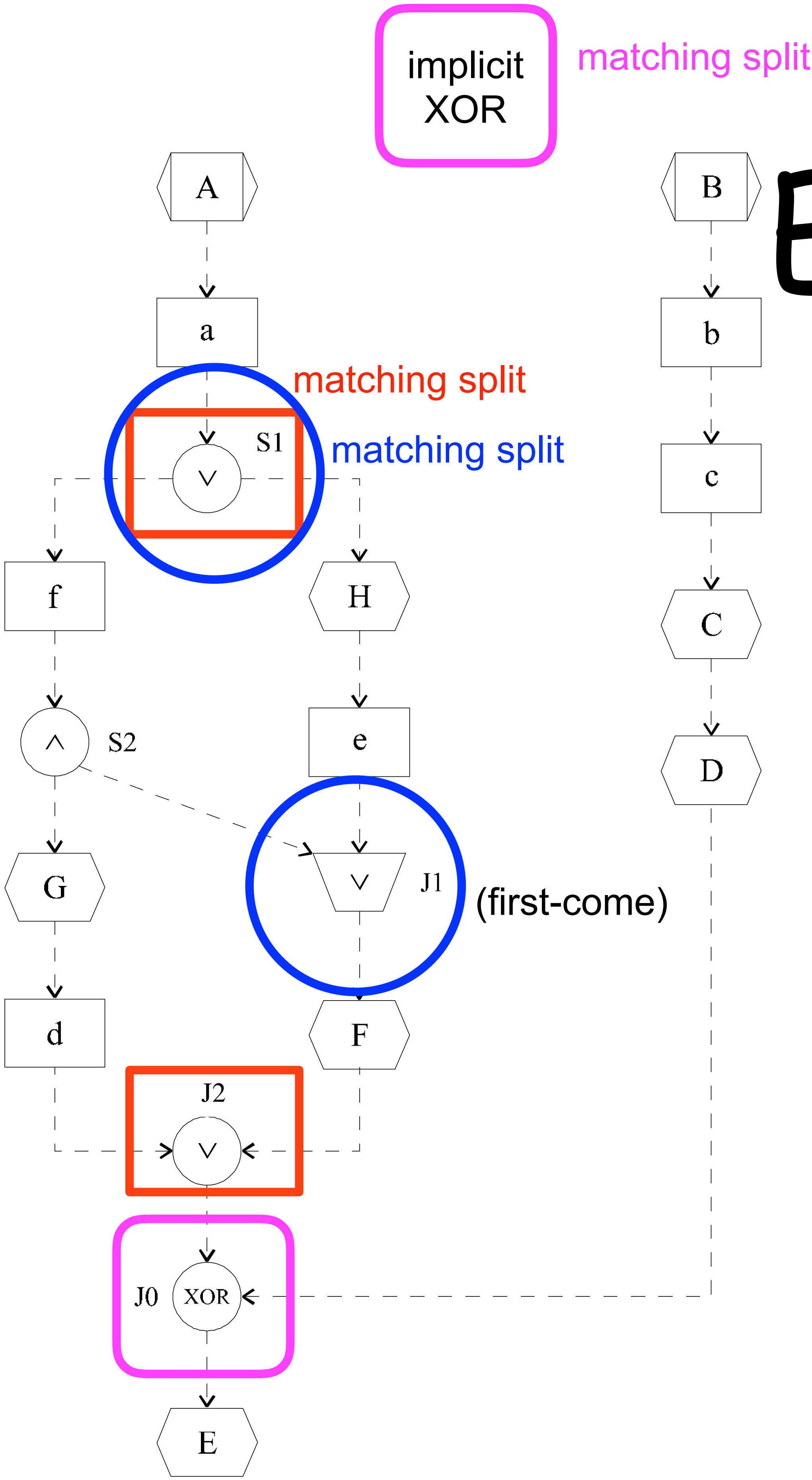
Sound?



Exercise

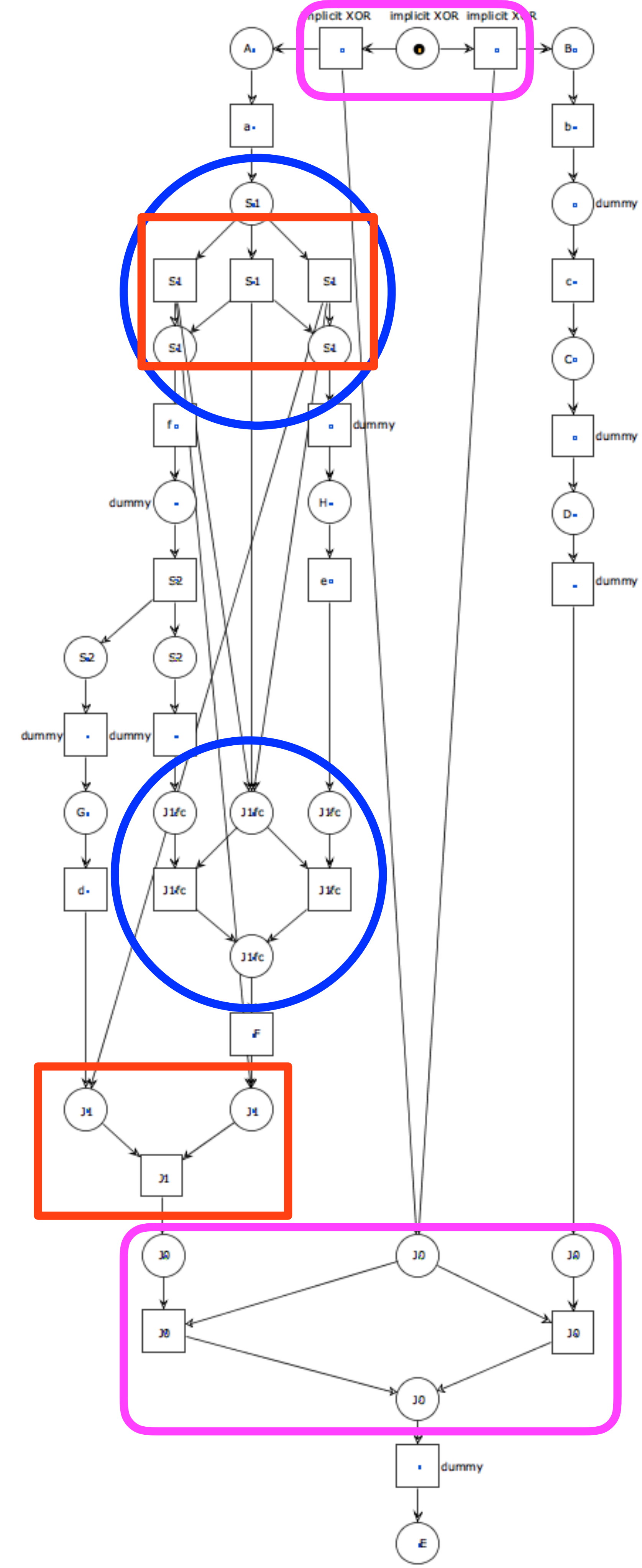
Sound?



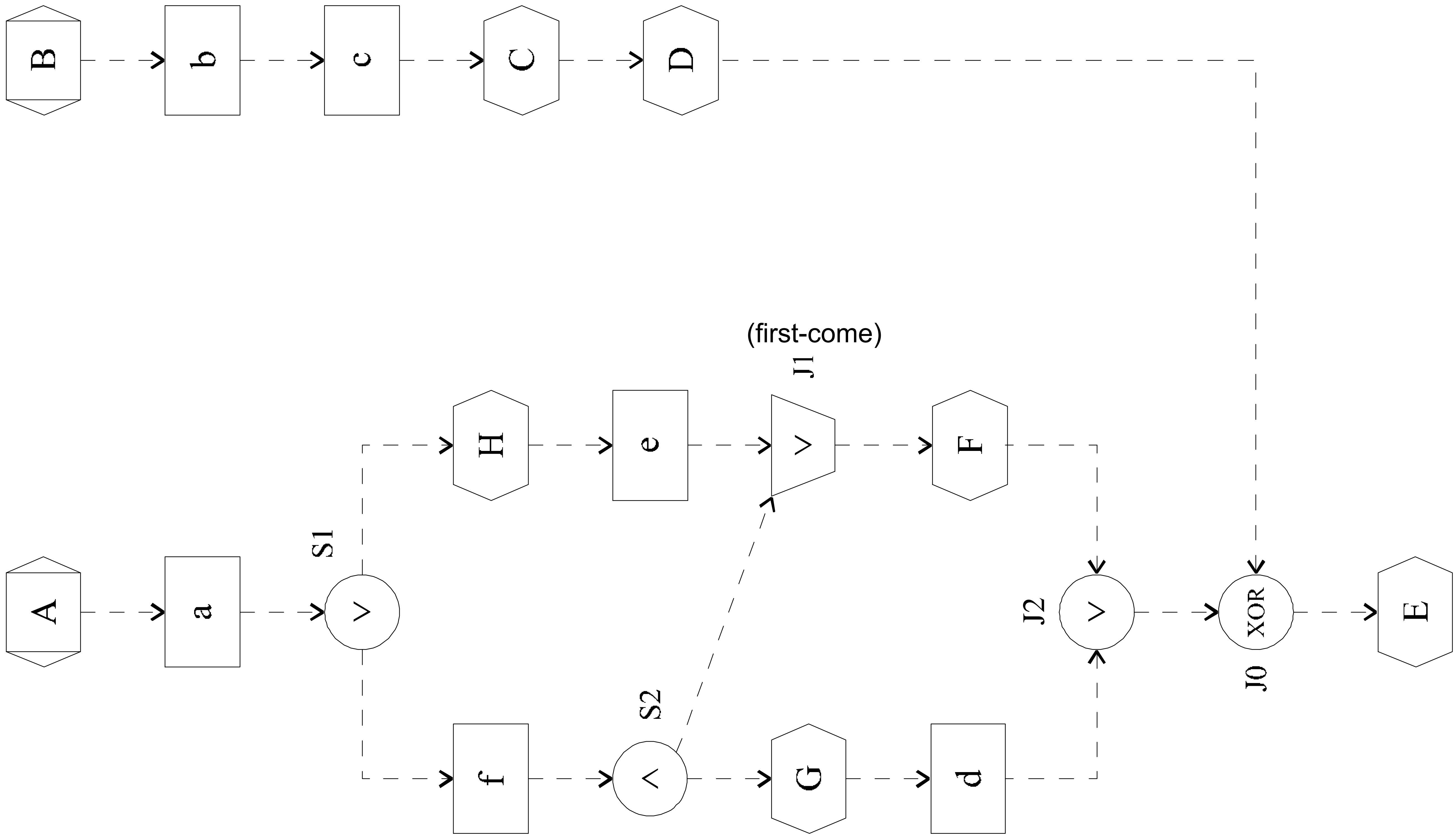


Exercise

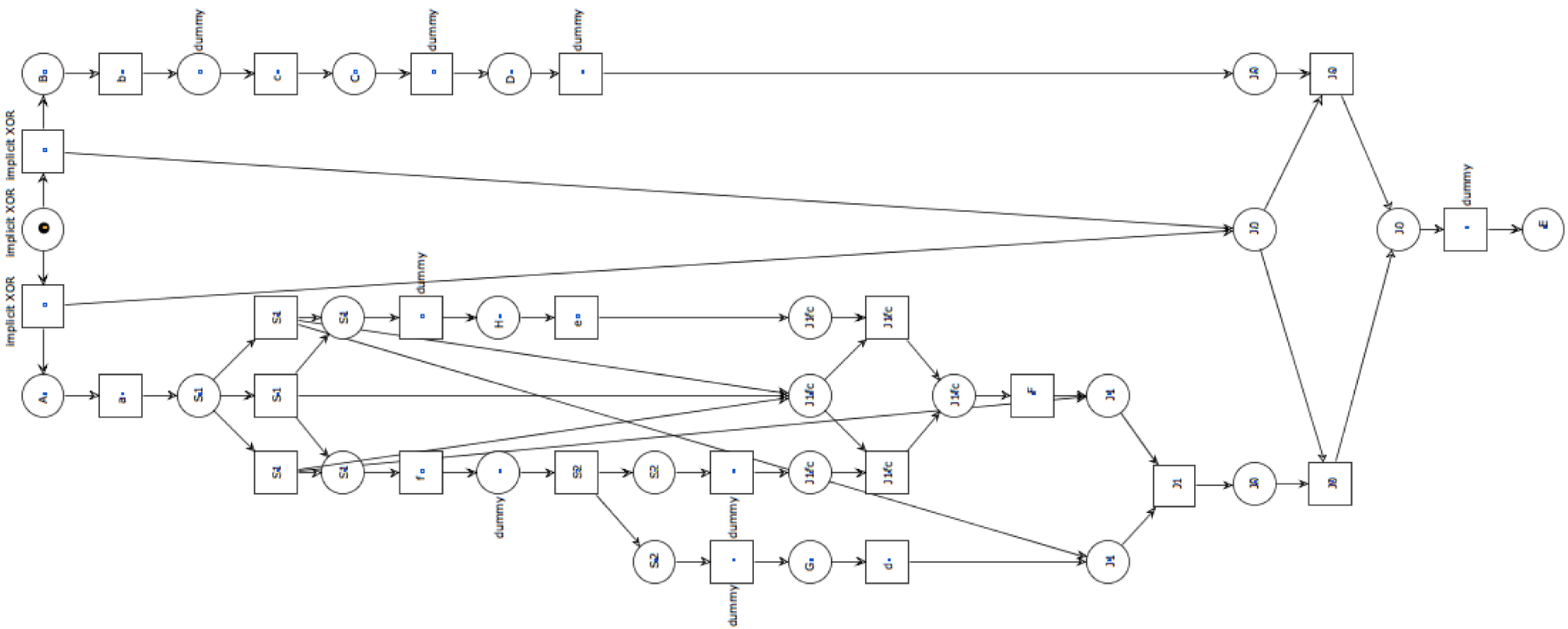
Sound?



ZOOM IN

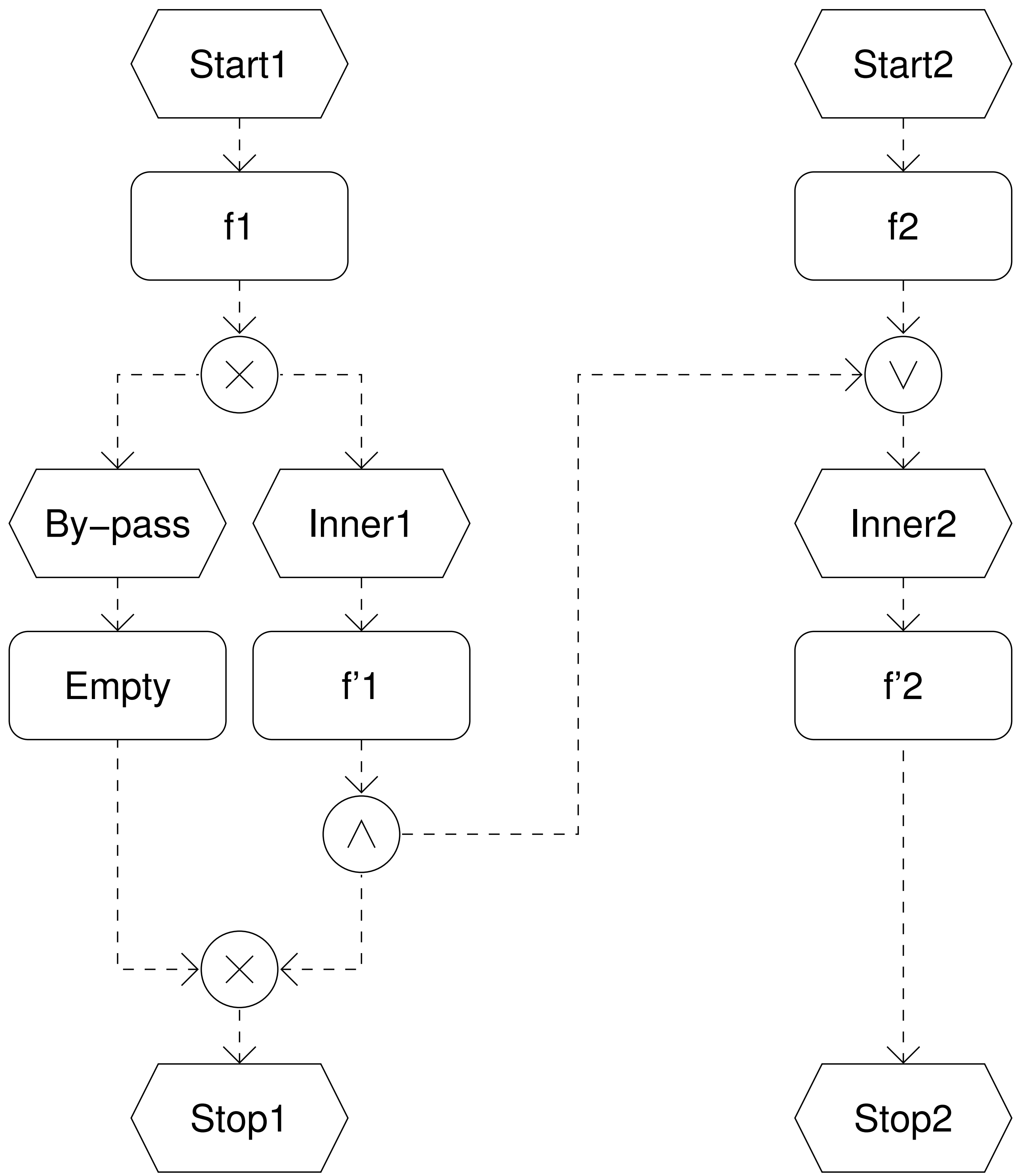


ZOOM IN



implicit XOR
implicit XOR
implicit XOR
dummy
dummy
dummy
dummy
dummy
dummy
dummy
dummy

Exercise



Sound?

Summary of problems

We need to decorate the EPC diagram
joins must be decorated with matching/corresponding splits
mismatched OR-joins must be decorated with policies

Split / join mismatch may induce unexpected behaviour

Possible introduction of dummy places and transitions

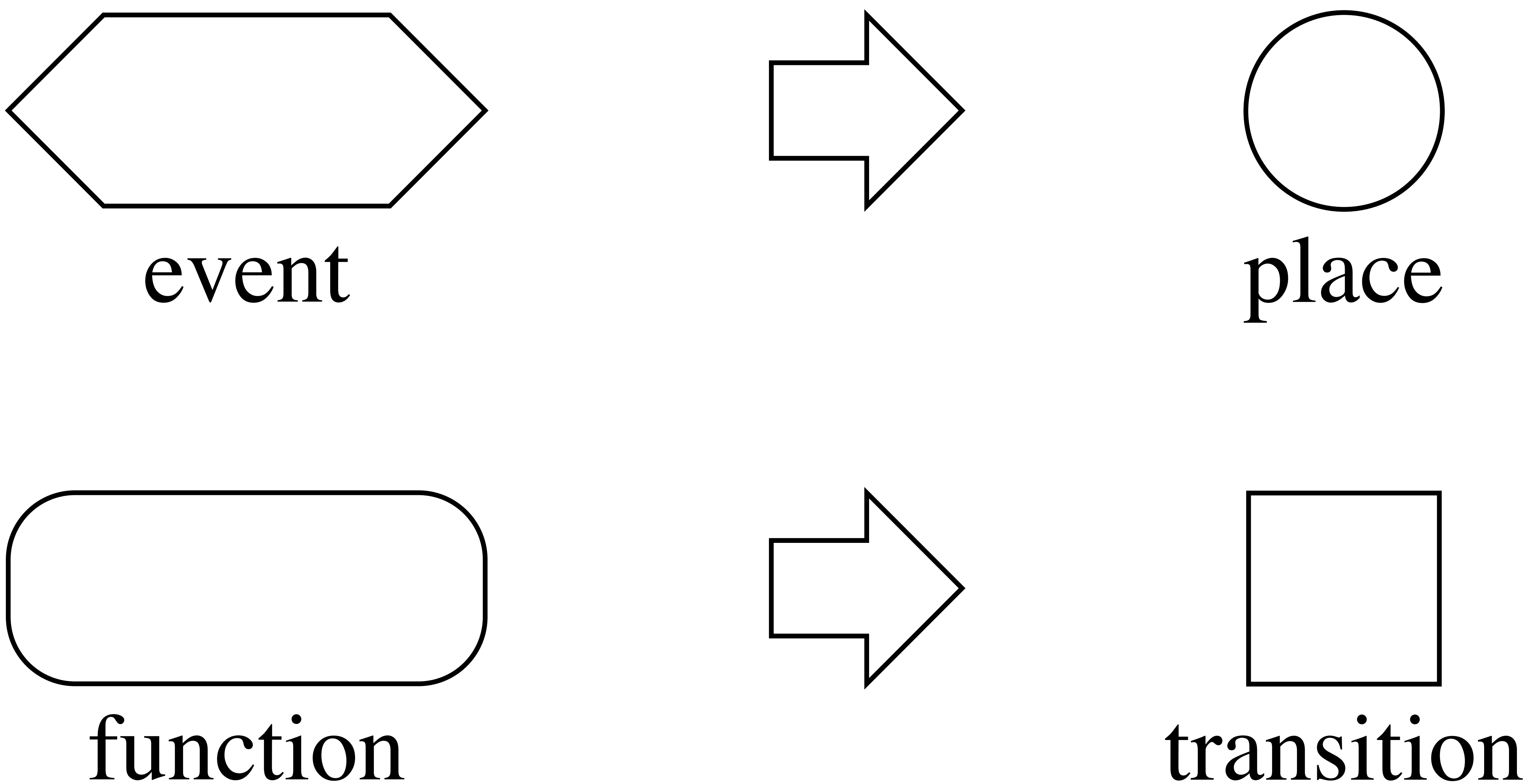
Second attempt
(no decoration required)

Simplified EPC

We rely on event / function alternation
along paths in the diagram
and also **along paths between two connectors**

OR-connectors are not considered

EPC 2 Petri nets: events and functions



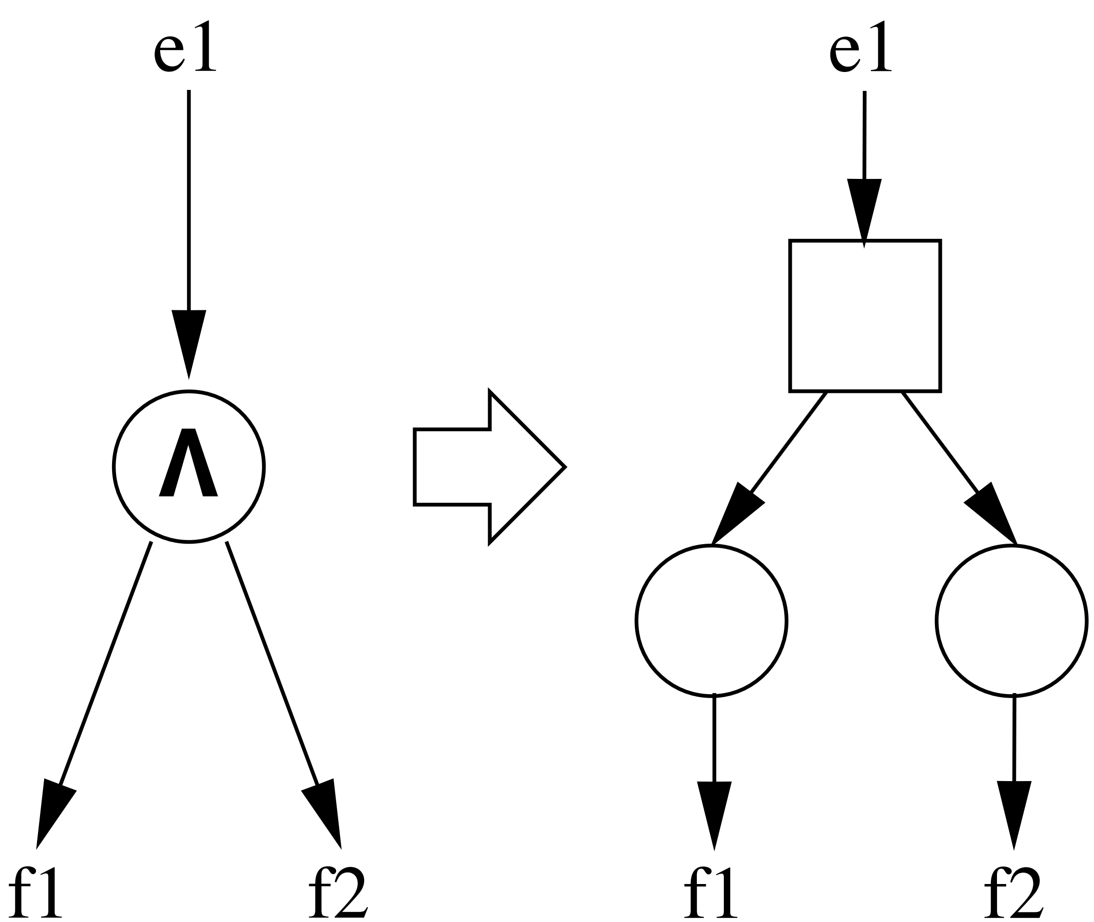
EPC 2 Petri nets: split/join connectors

The translation of logical connectors
depends on the context:

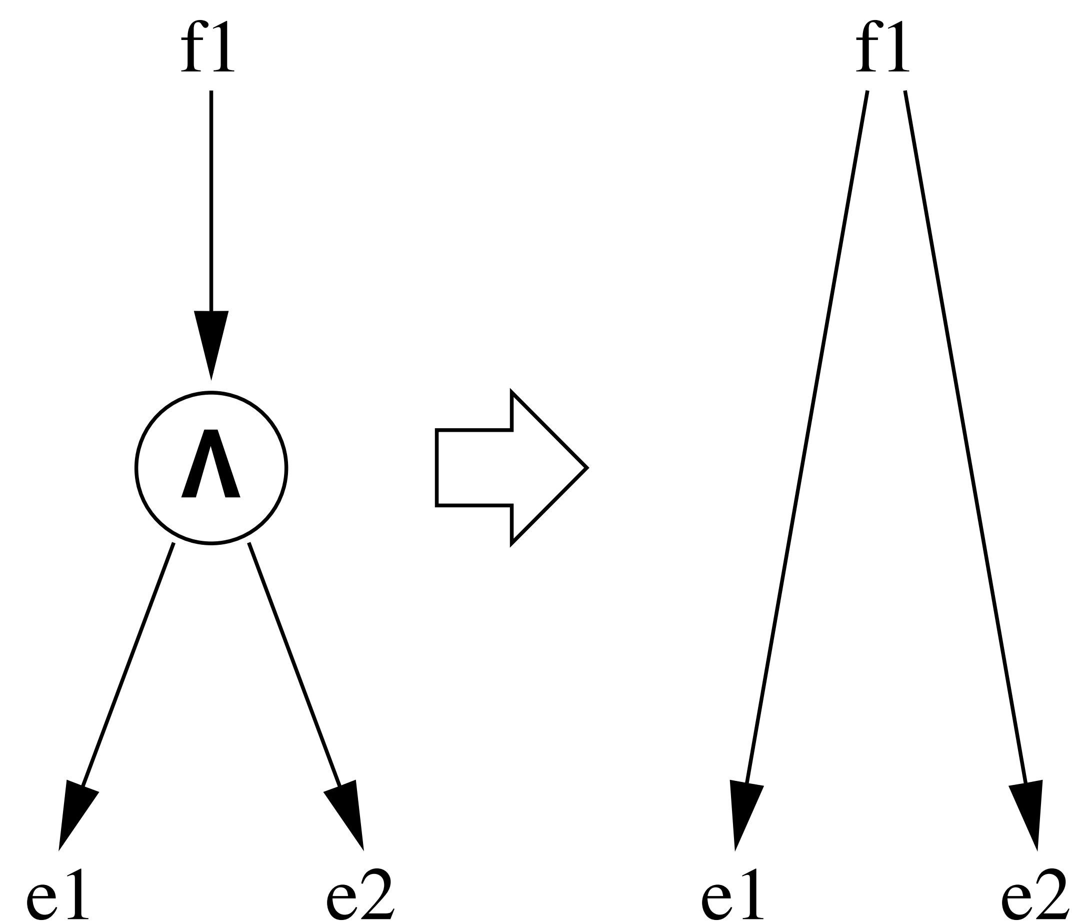
if a connector connects **functions to events**
we apply a certain translation

if it connects **events to functions**
we apply a different translation

EPC 2 Petri nets: AND split

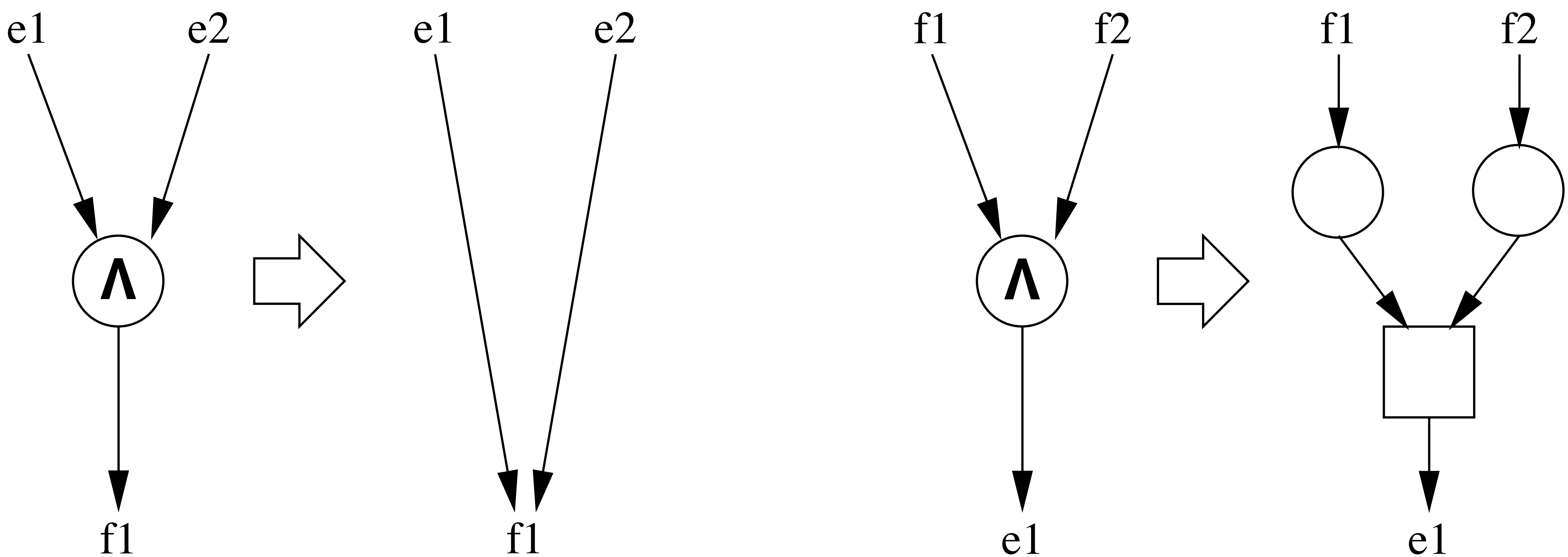


(event to functions)



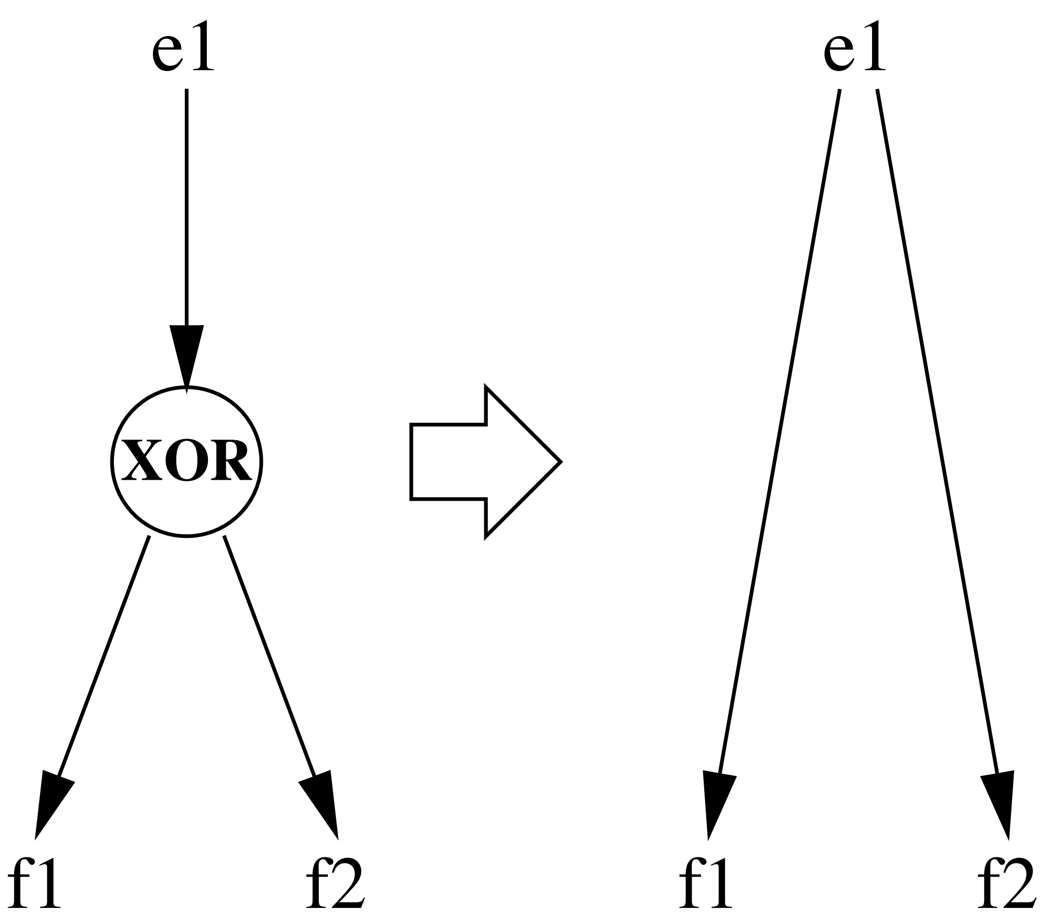
(function to events)

EPC 2 Petri nets: AND-join

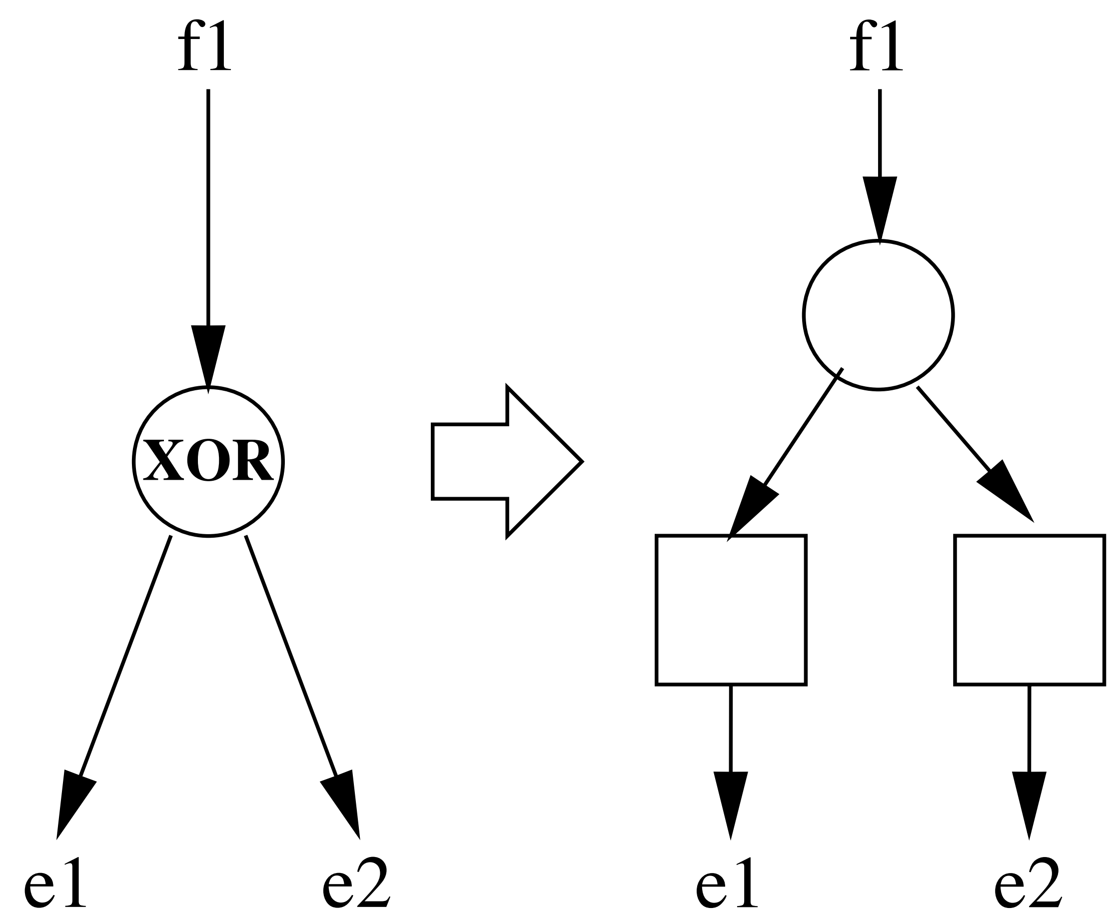


(events to function) (functions to event)

EPC 2 Petri nets: XOR split

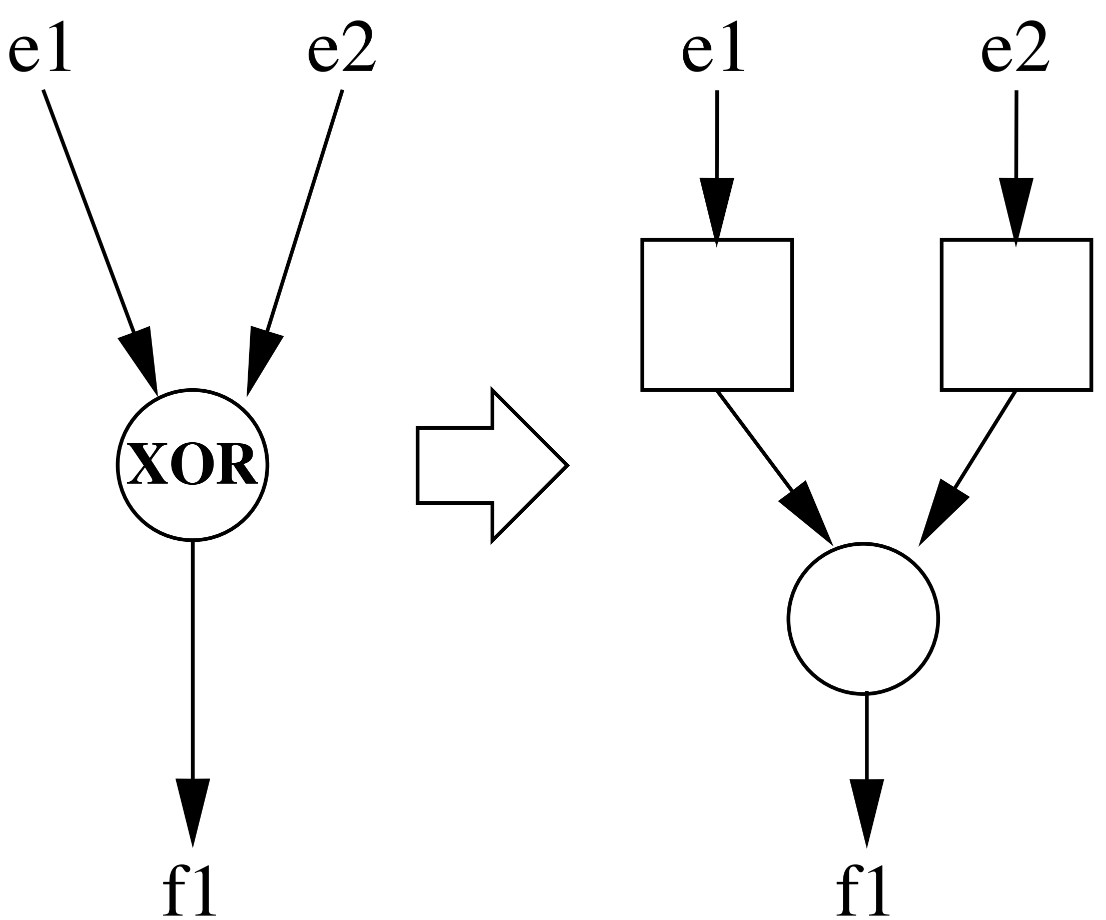


(event to functions)

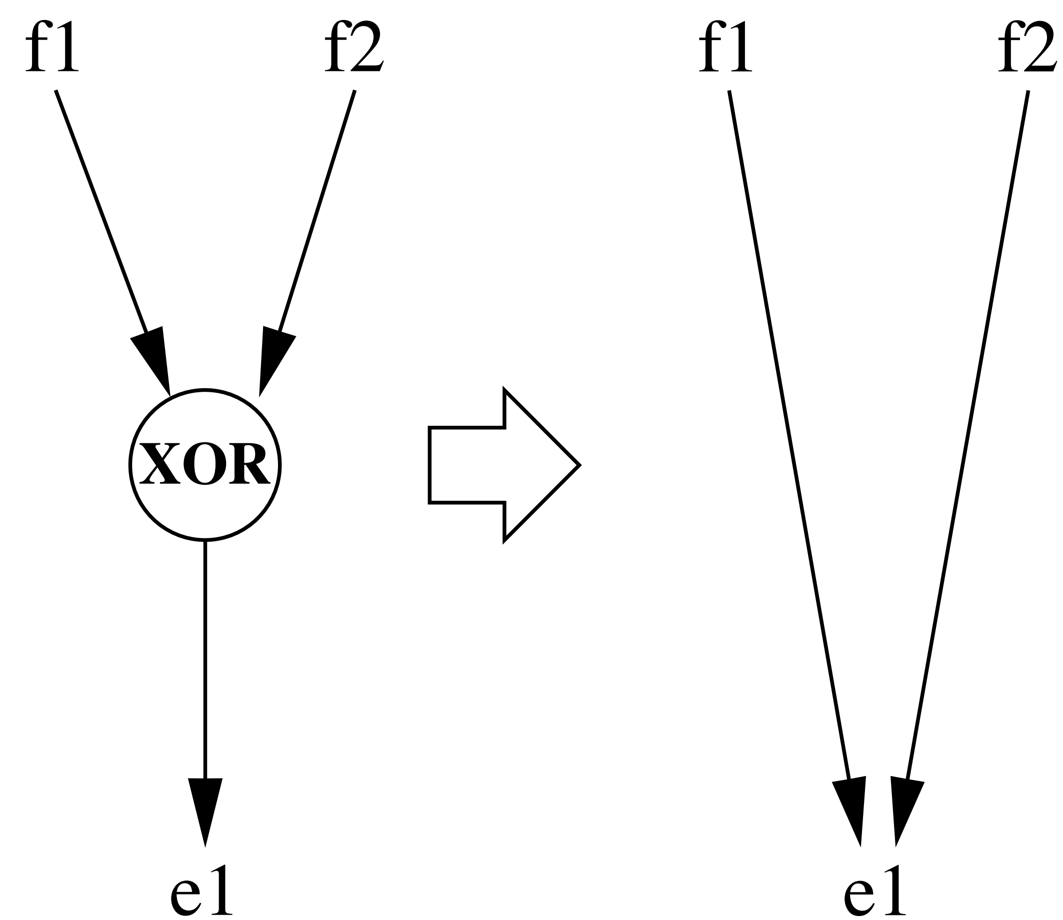


(function to events)

EPC 2 Petri nets: XOR join

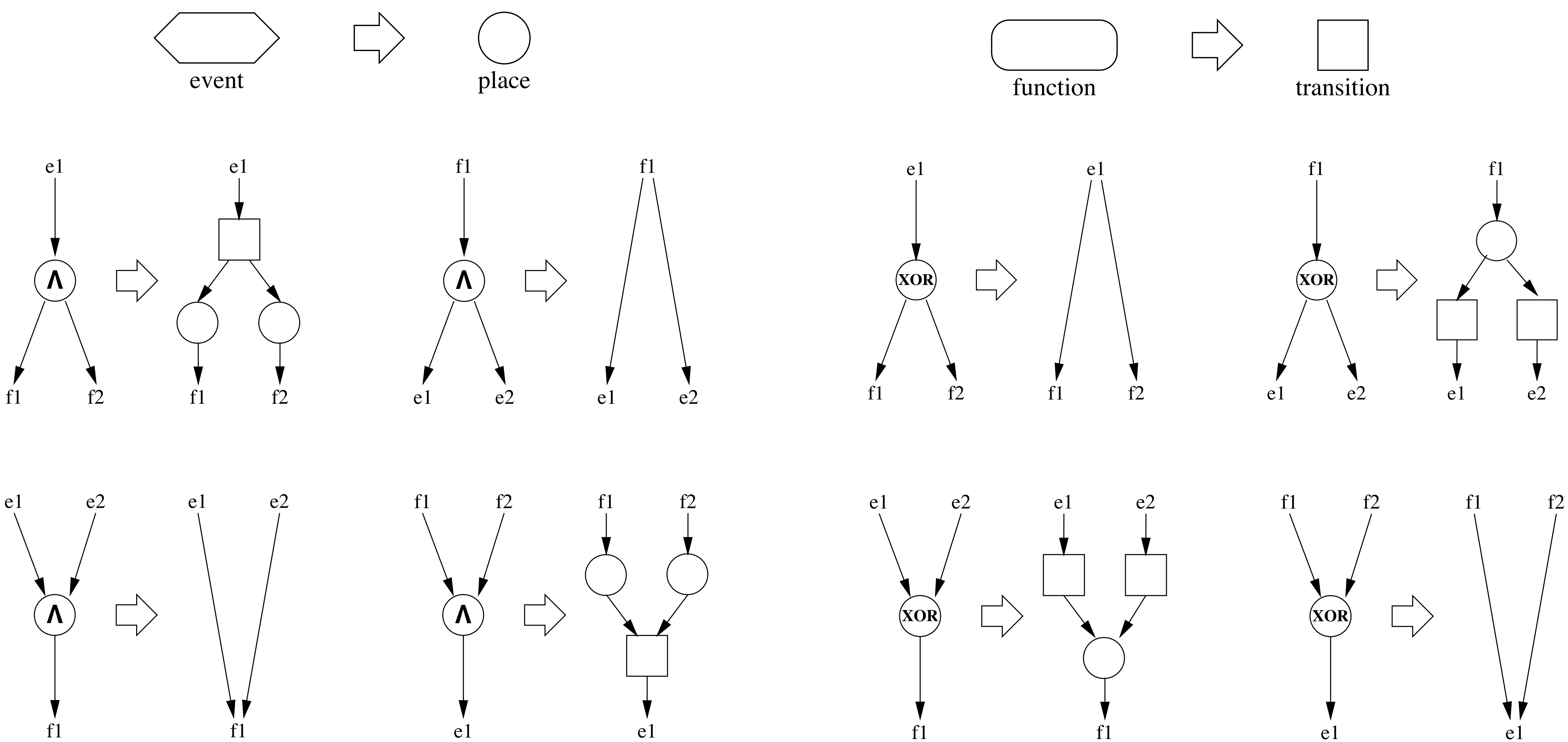


(events to function)

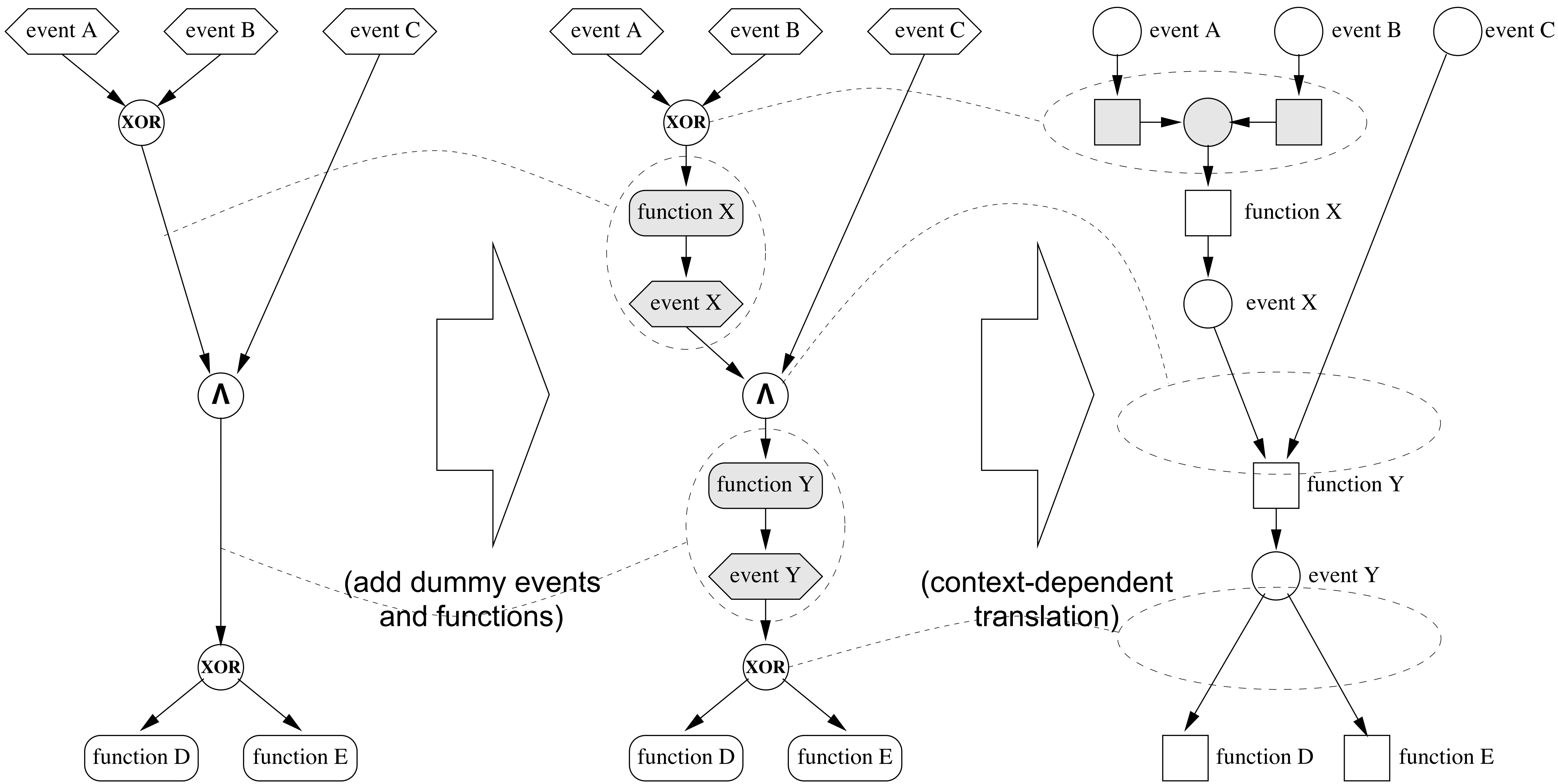


(functions to event)

EPC 2 Petri nets: at a glance



EPC 2 nets: Example

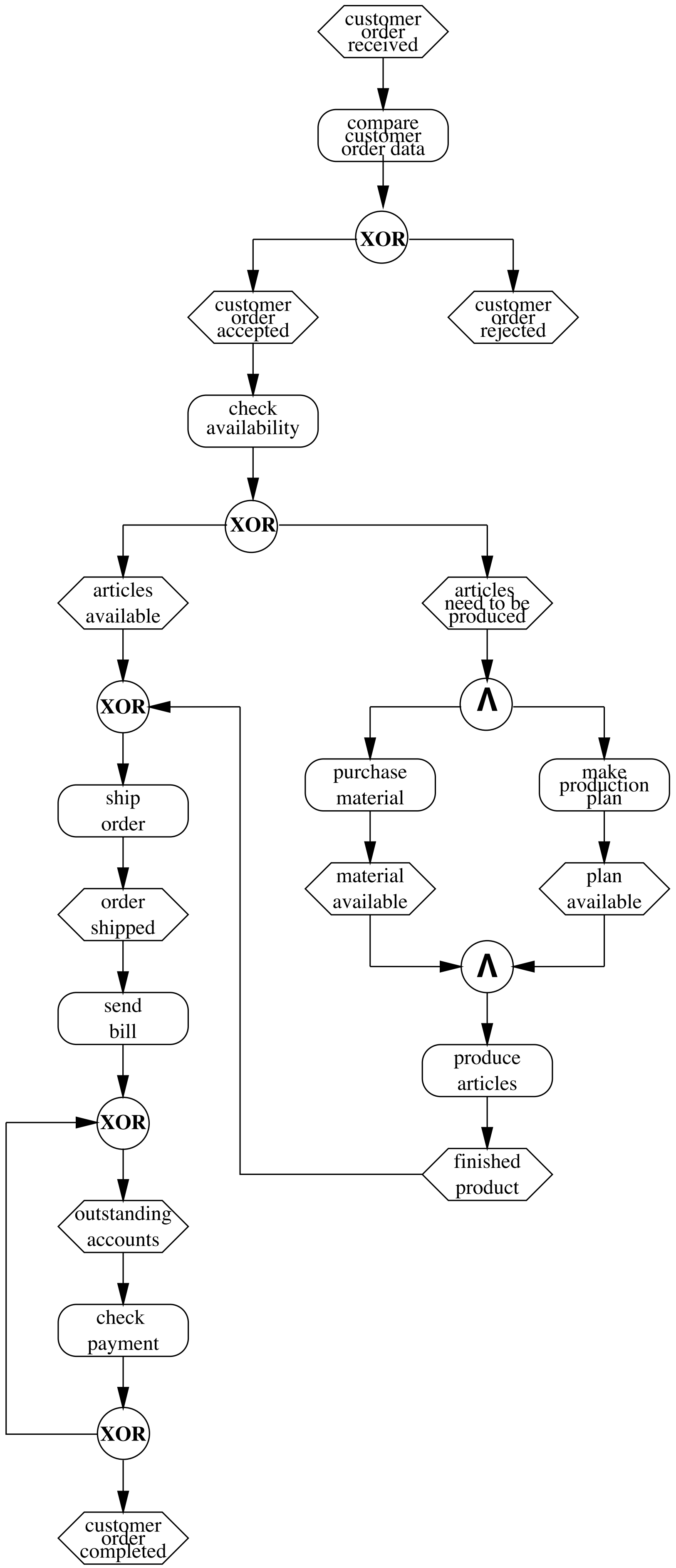


Outcome

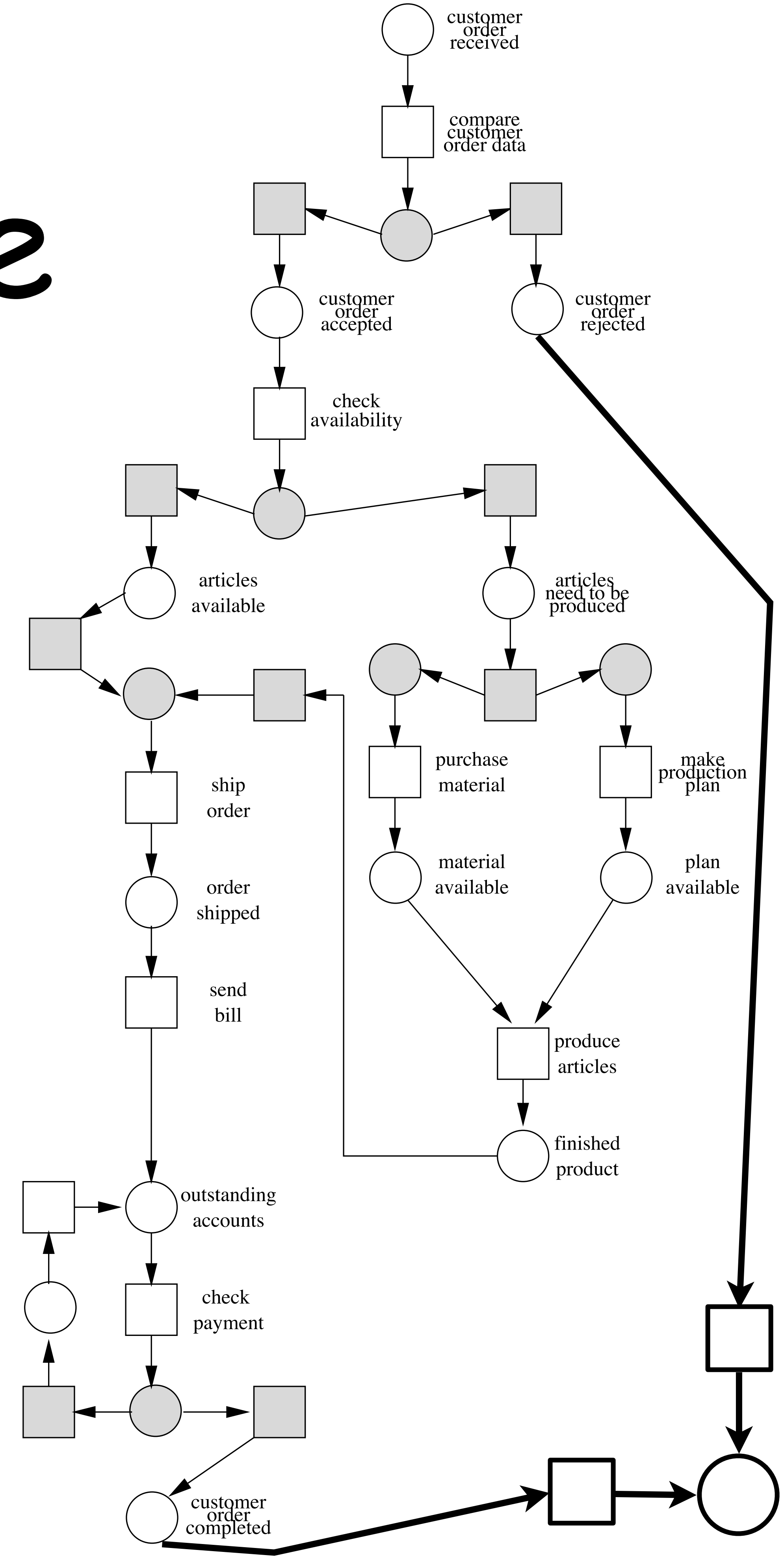
From any EPC we derive a free-choice net

Moreover, if we add unique start / end events
(and suitable transitions attached to them)
the net is a workflow net

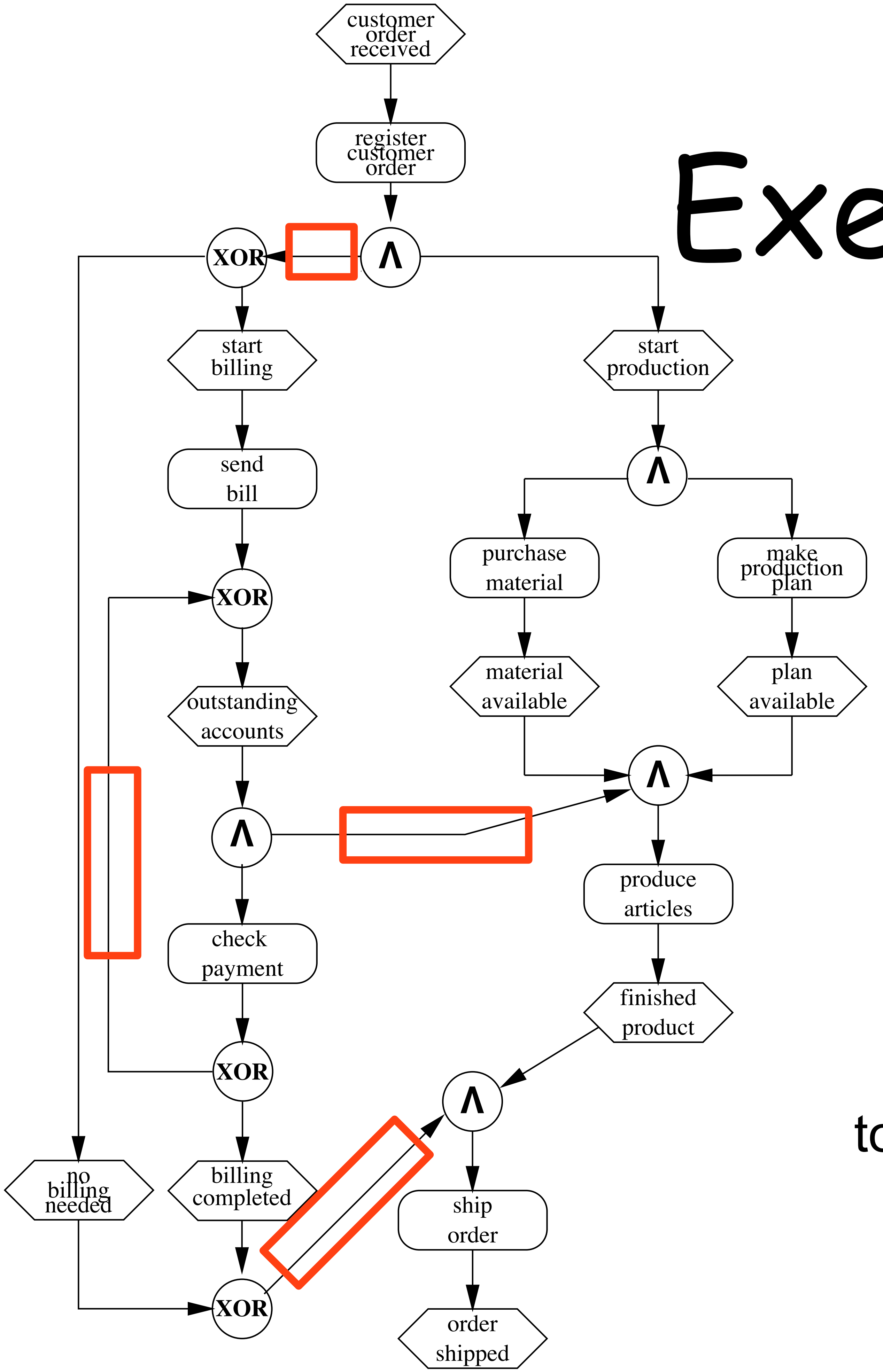
Exercise



Check it sound!



Exercise



Sound?

(remind
to add dummy events and functions
and
to guarantee event/function alternation)

Relaxed soundness
(a third attempt)

Popularity vs superiority

EPC are a quite successful, semiformal notation

They lack a comprehensive and consistent syntax
They lack even more a corresponding semantics

You may **restrict the notation**, but people will prefer the more liberal (flexible) syntax and ignore the guidelines

You may **enrich the notation**, but people will dislike or misinterpret implementation policies

What are ultimately business process?

Graphical language to **communicate** concepts

Careful selection of symbols
shapes, colors, arrows
(the alphabet is necessary for communication)

Greatest common denominator of the people involved

Intuitive meaning
(verbal description, no math involved)

Remember some good old friends

Chief Process Officer

Process participants

System architect

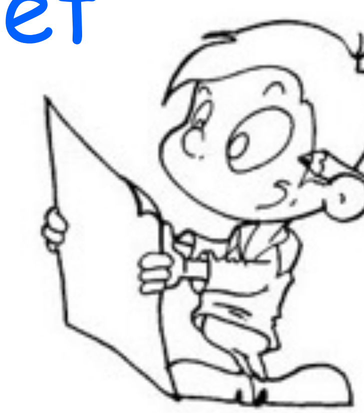
EPC

Business engineer

Knowledge worker

Process responsible

WFnet



System developer

Process designer

A secret not to tell

Ambiguity is useful in practice!

The more ways are to interpret a certain construct
the more likely an agreement will be reached

A pragmatic consideration

Moreover

in the **analysis phase**
the participants may not be ready
to **finalise** the specification
and decide for the **correct interpretation**

Yet

it is important to find out **flaws** as **soon** as possible

Consequences

Ambiguous process descriptions
arise in the **design phase**

therefore

we need to fix a **formal representation**
that **preserves all ambiguities**

Problem

EPC is fine (widely adopted)

WF nets offer a useful tool

but

Soundness is too demanding at early stages

Relaxed soundness

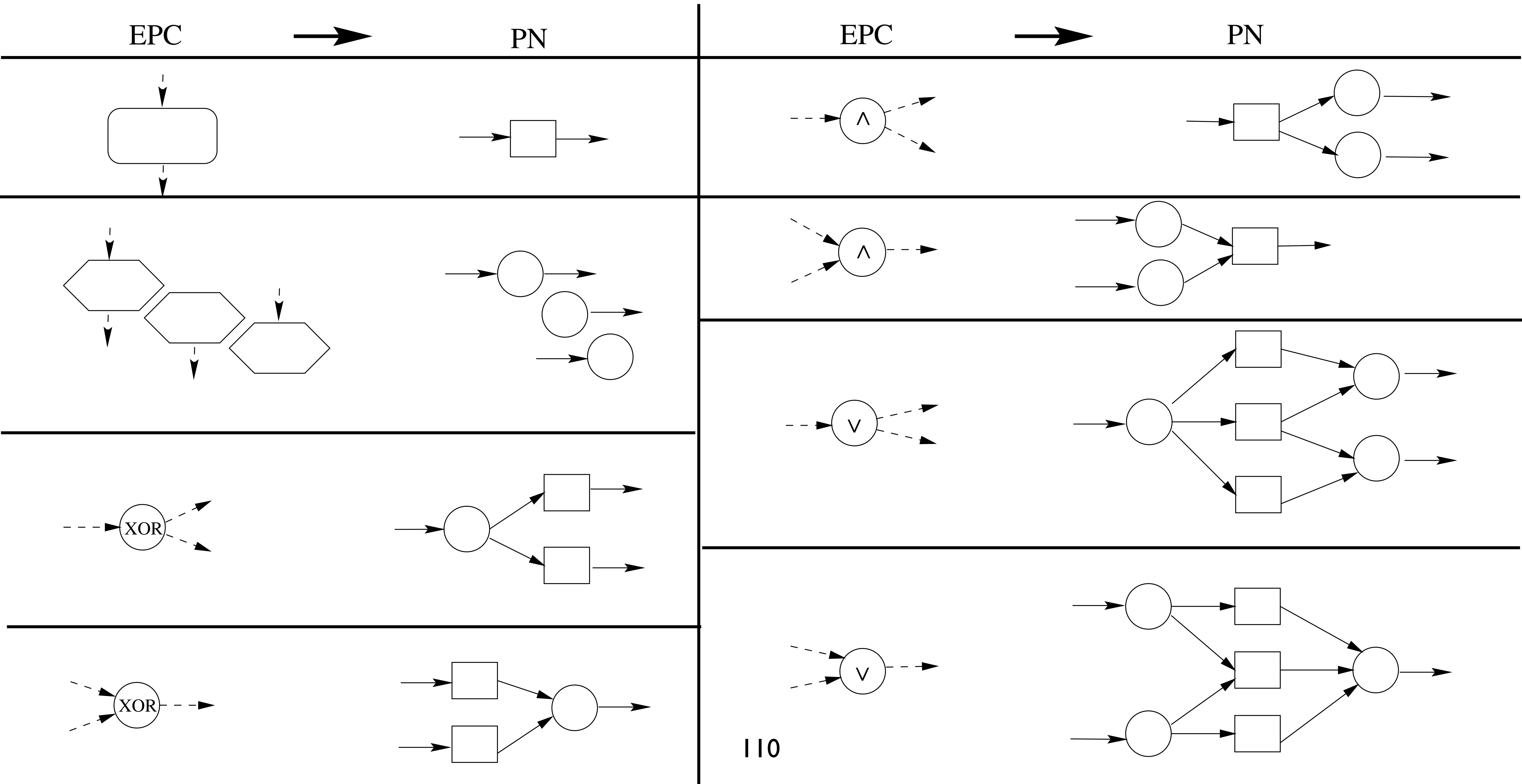
A **sound** behaviour:
we move from a start event to an end event
so that nothing blocks or remains undone

Execution paths leading to **unsound** behaviour
can be used to infer potential mistakes in the EPC

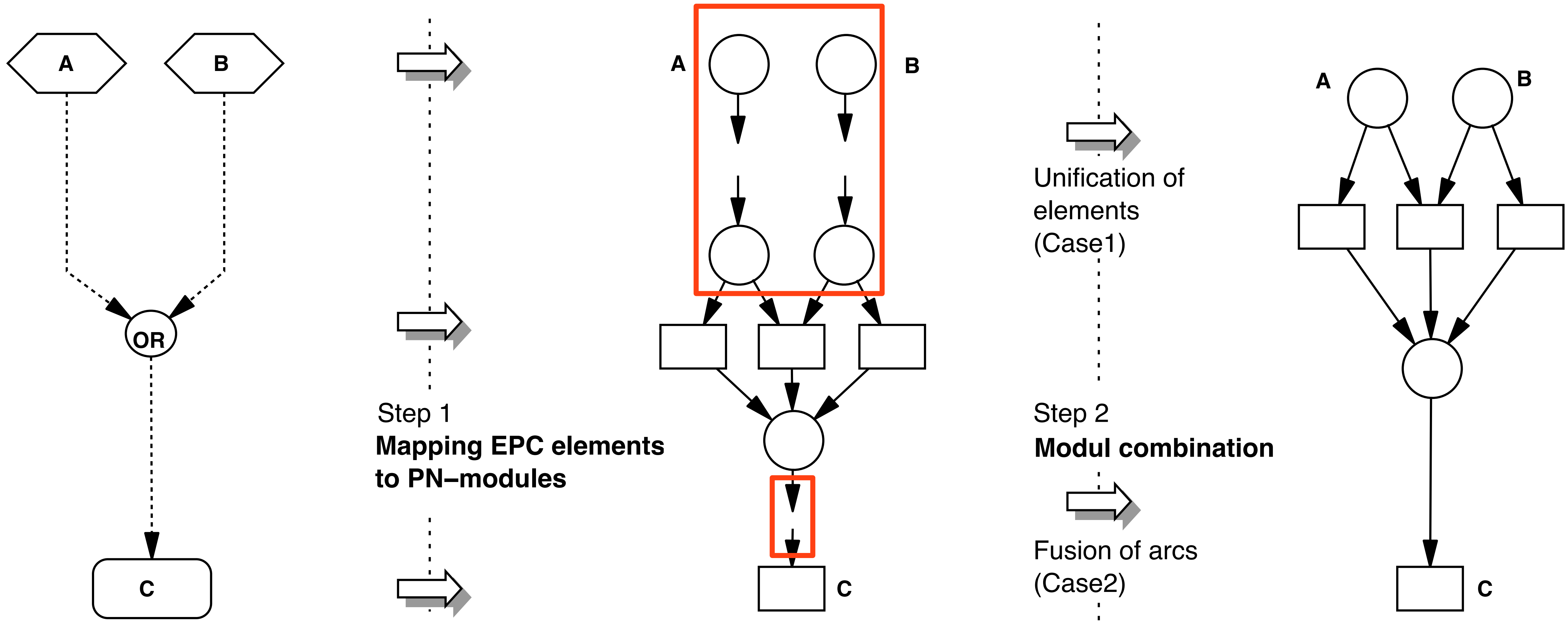
If some unsound behaviour is possible
but **enough** sound paths exist
the process is called **relaxed sound**

A 3-steps approach
(keep it simple!)

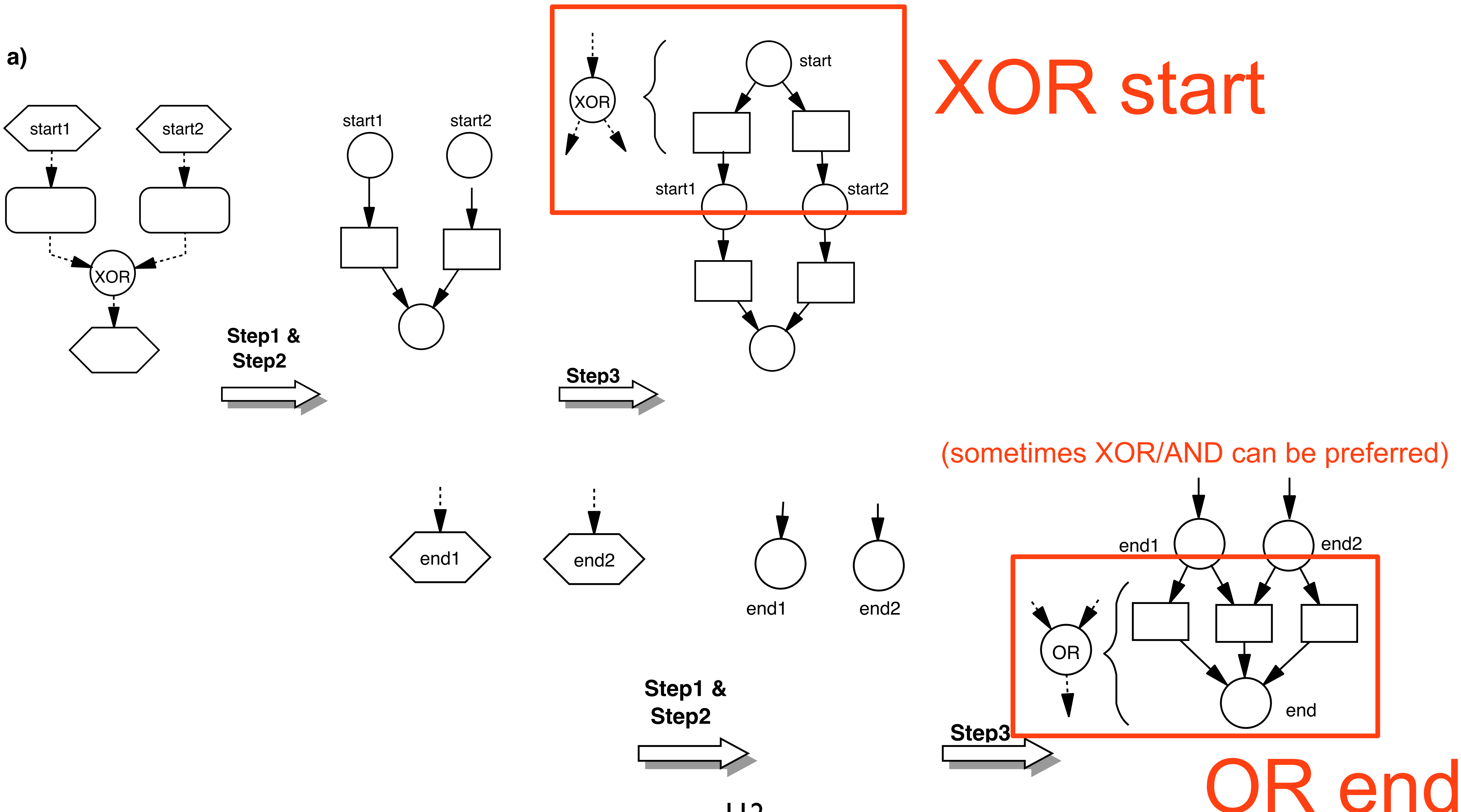
Step 1: straightforward element map



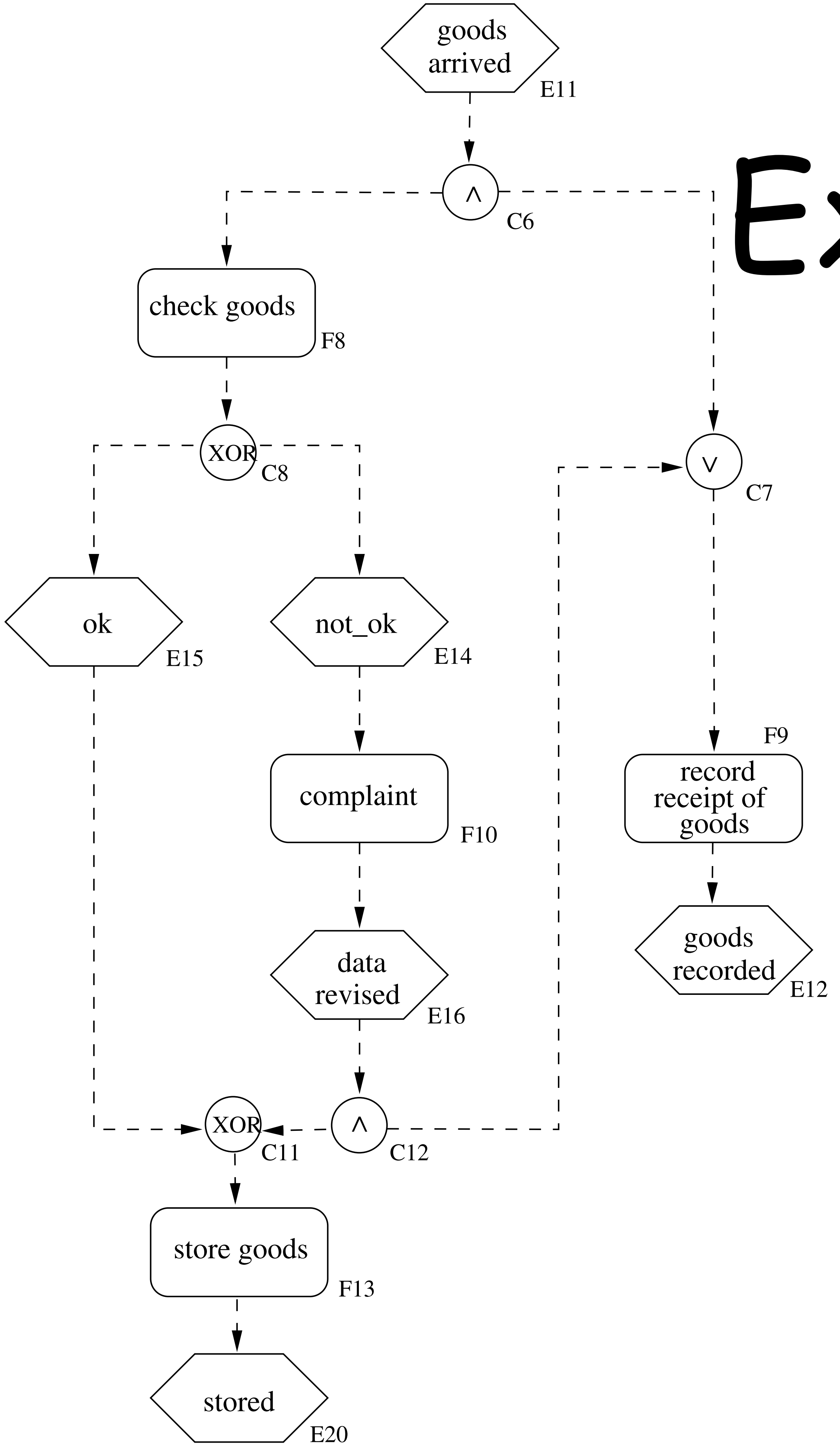
Step 2: element fusion



Step 3: add unique start / end

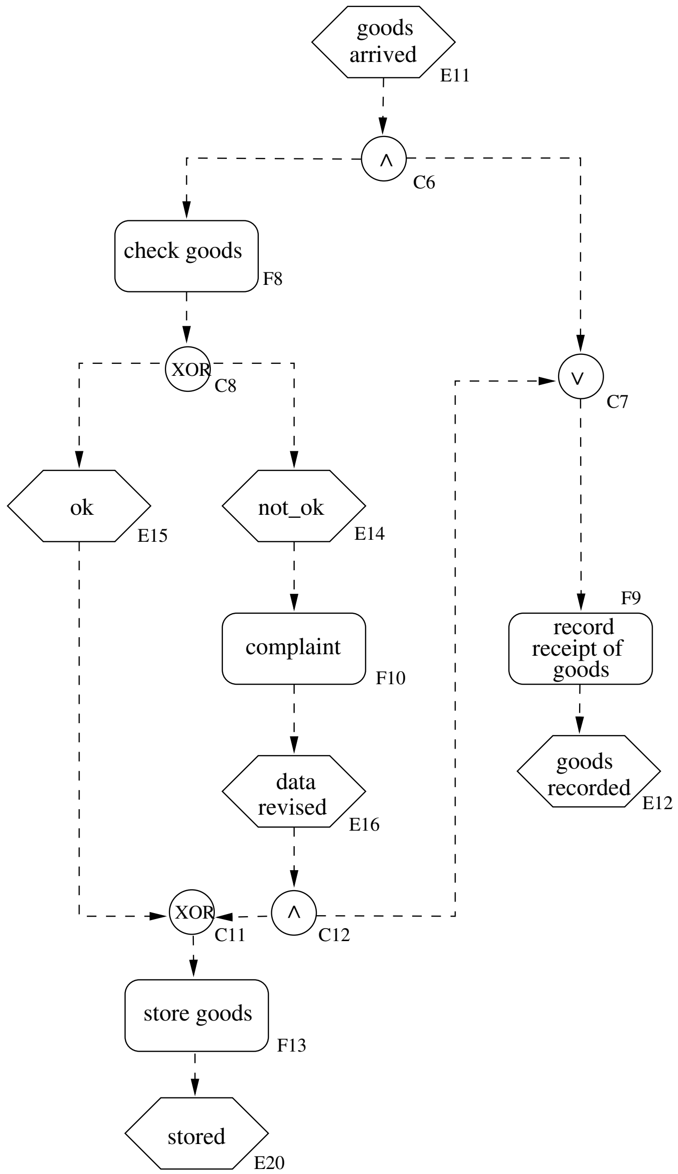


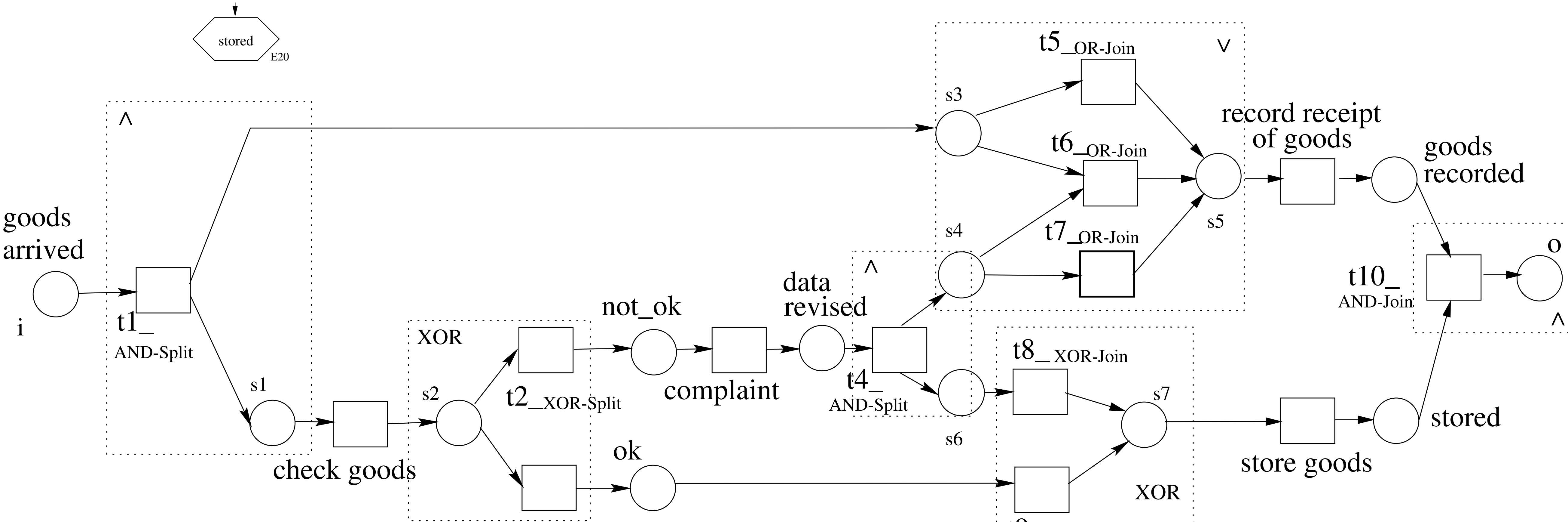
Example

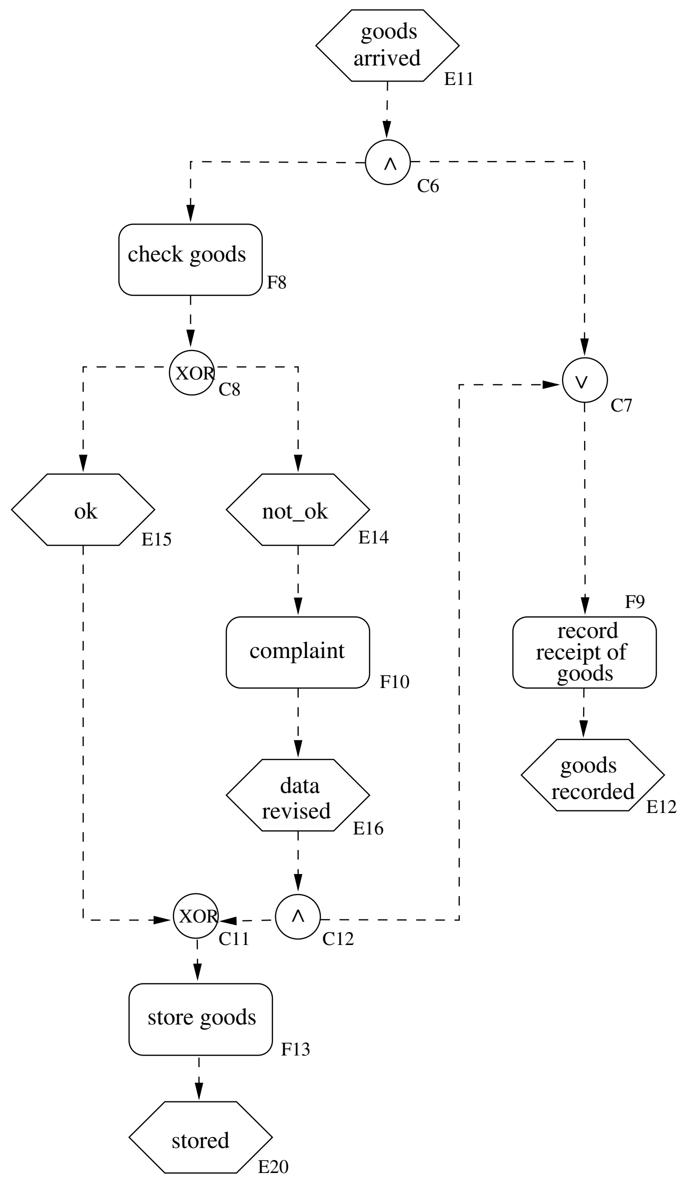


Sound?

Example

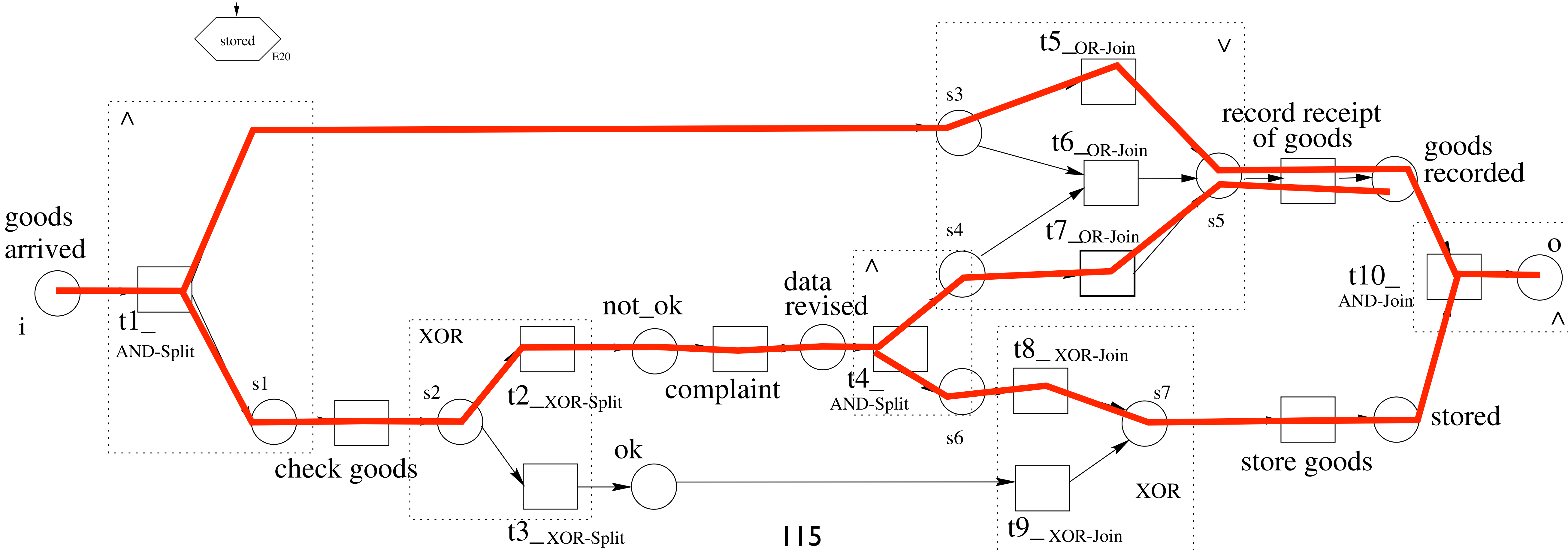

goods arrived
E11
∧
C6
check goods
F8
XOR
C8
∨
C7
ok
E15
not_ok
E14
complaint
F10
F9
record receipt of goods
goods recorded
E12
data revised
E16
XOR
C11
∧
C12
store goods
F13
stored
E20


t5_OR-Join
∨
s3
t6_OR-Join
record receipt of goods
goods recorded
∧
goods arrived
s4
t7_OR-Join
s5
o
t10_
AND-Join
i
t1_
AND-Split
data revised
∧
not_ok
XOR
t4_
AND-Split
t8_ XOR-Join
s7
s1
s2
t2_ XOR-Split
complaint
s6
stored
∧
ok
check goods
store goods
XOR
t3_ XOR-Split
t9_ XOR-Join



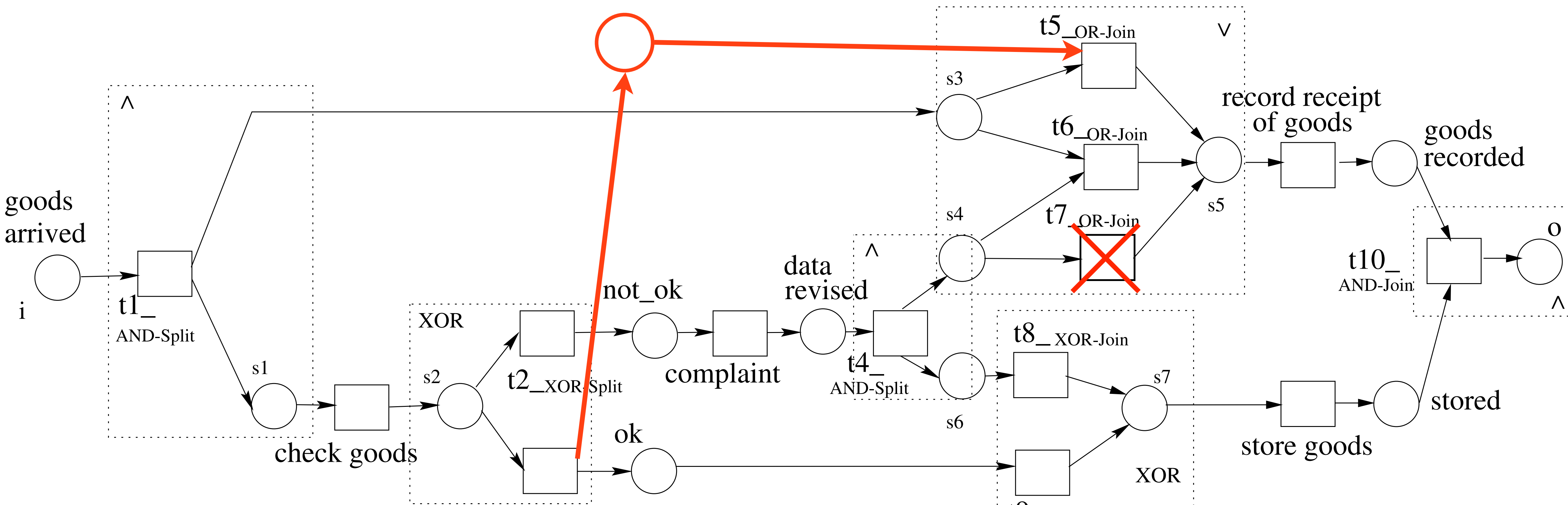
Example

Not sound!



Example

We can turn it to sound, but:
small changes in the net, can be problematic in EPC



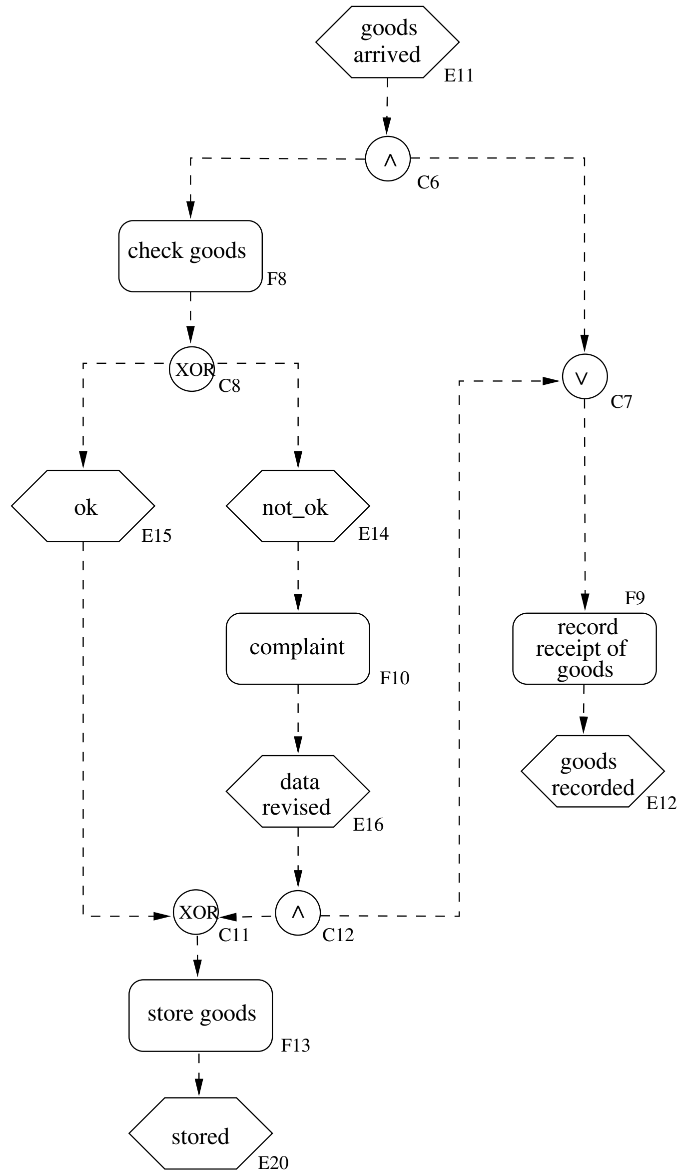
Relaxed soundness: formally

Definition: A WF net is **relaxed sound** if every transition belongs to a firing sequence that starts in state i and ends in state o

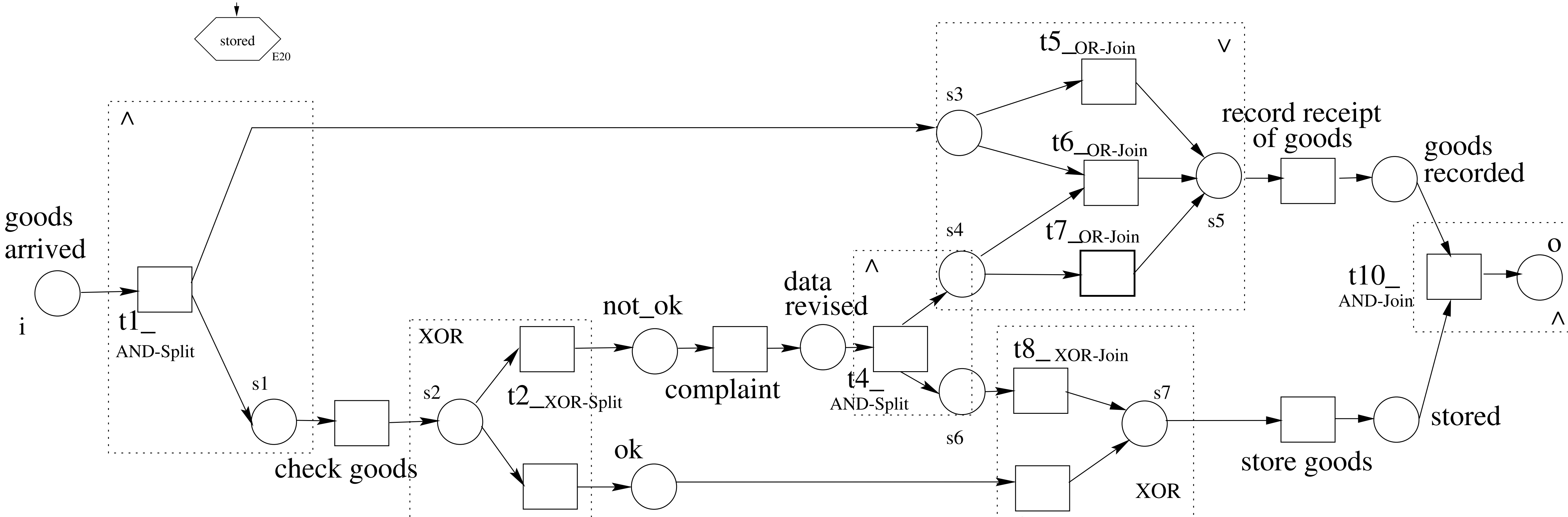
$$\forall t \in T. \exists M, M'. i \rightarrow^* M \xrightarrow{t} M' \rightarrow^* o$$

(it is sound "enough", in the sense that all transitions are covered by at least one sound execution)

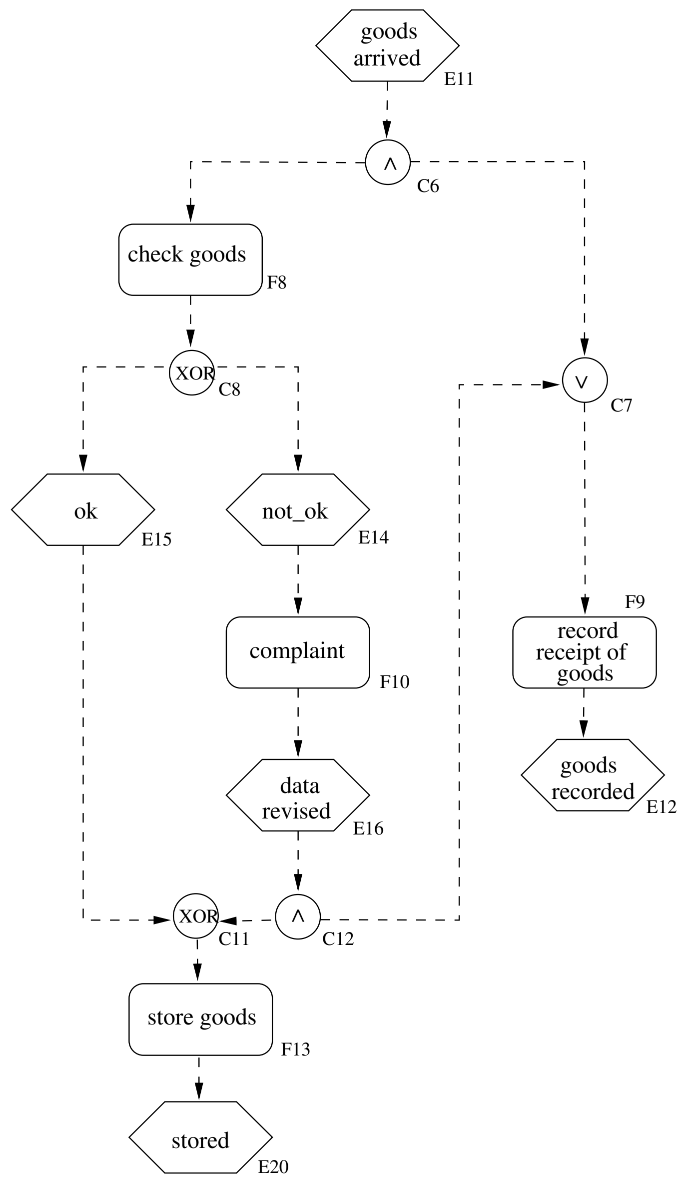
Example



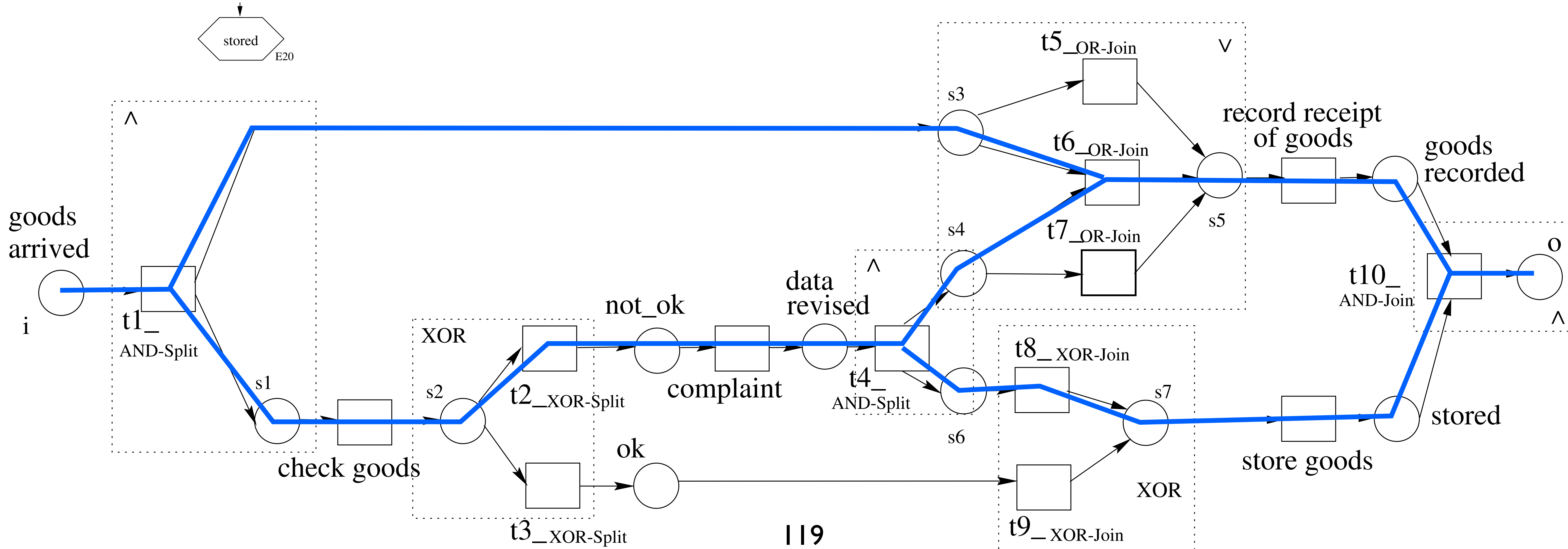
Relaxed sound?

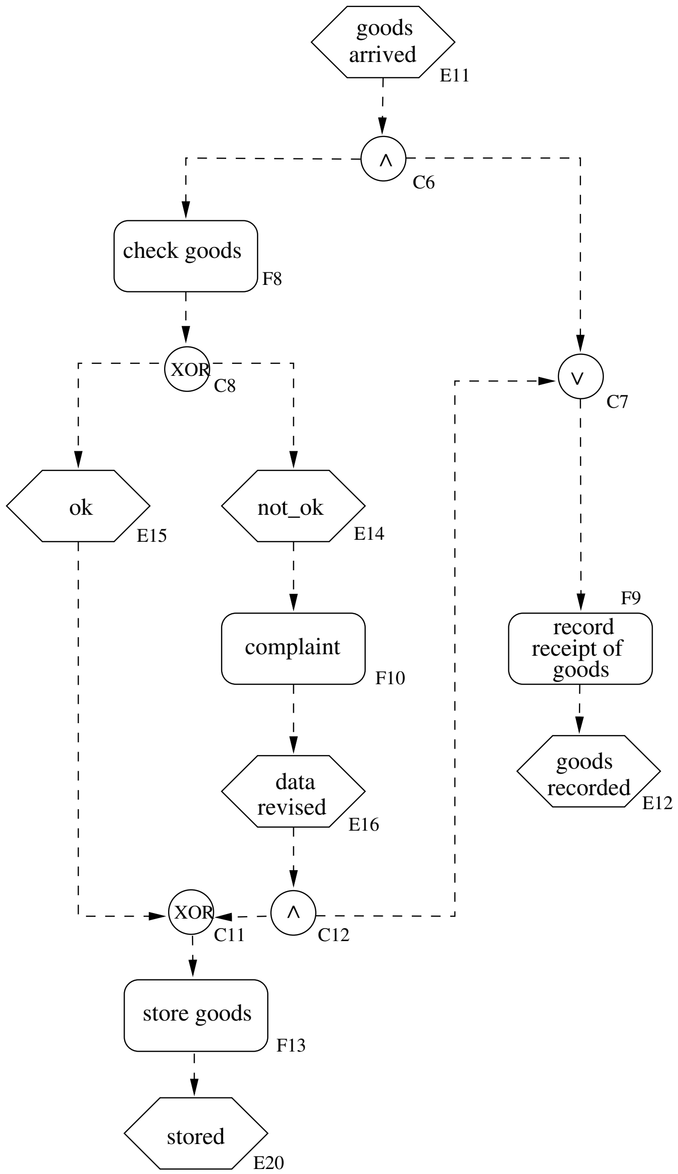


Example



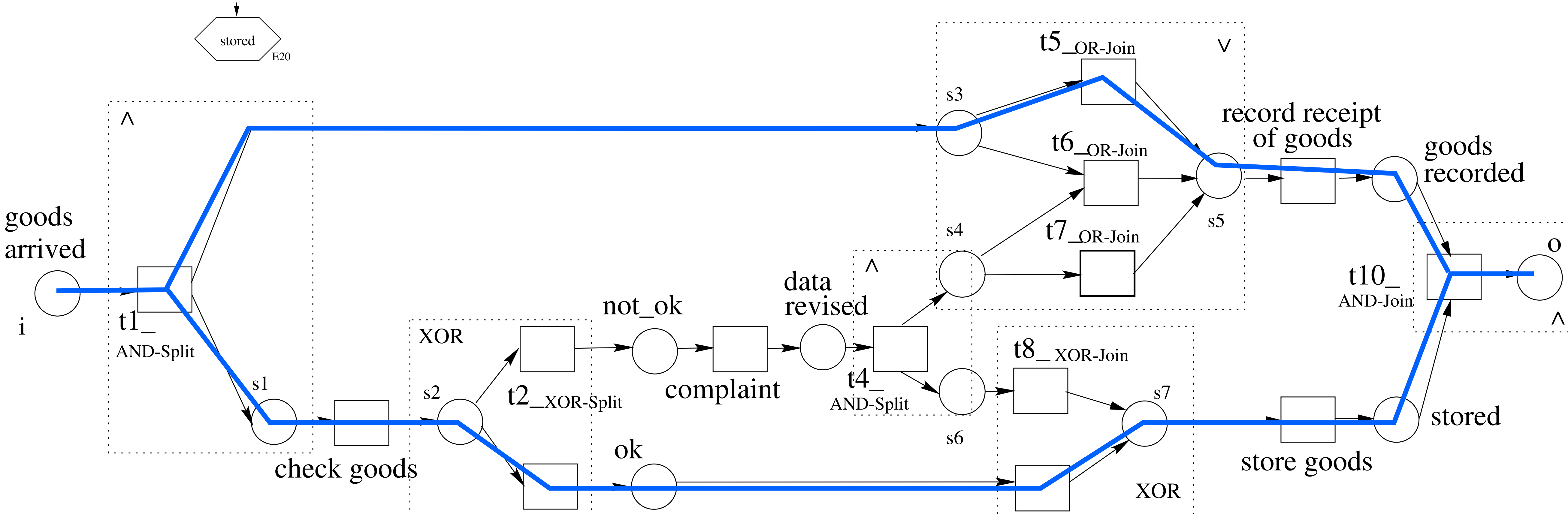
Relaxed sound?





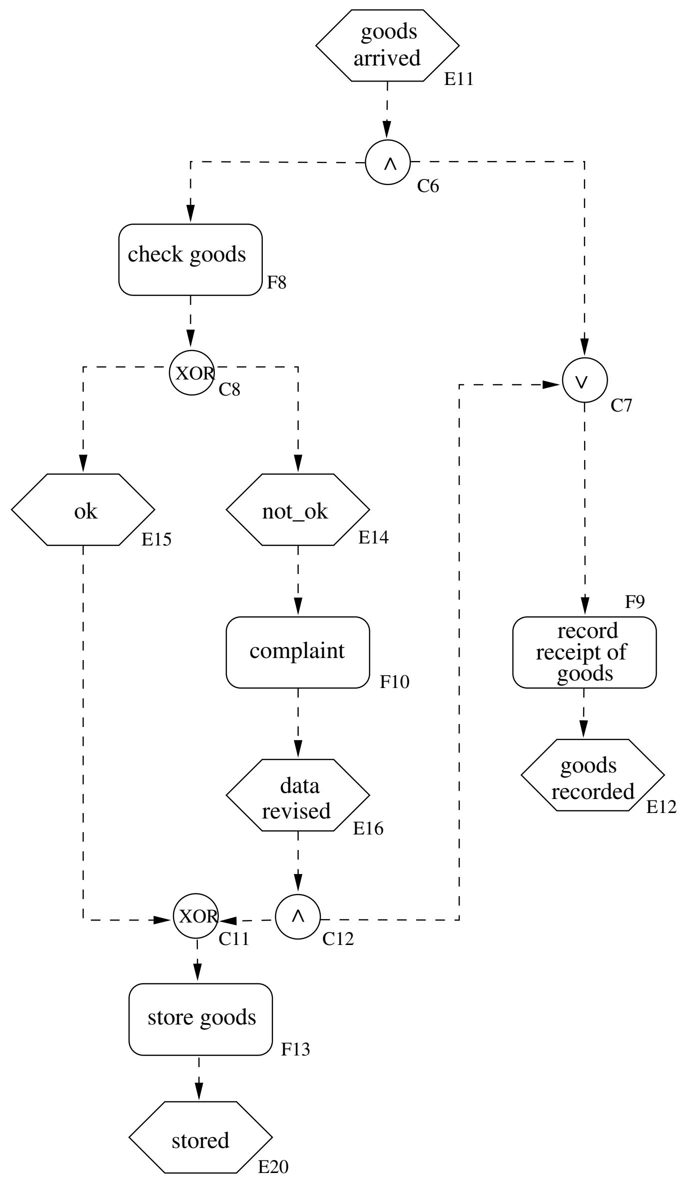
Example

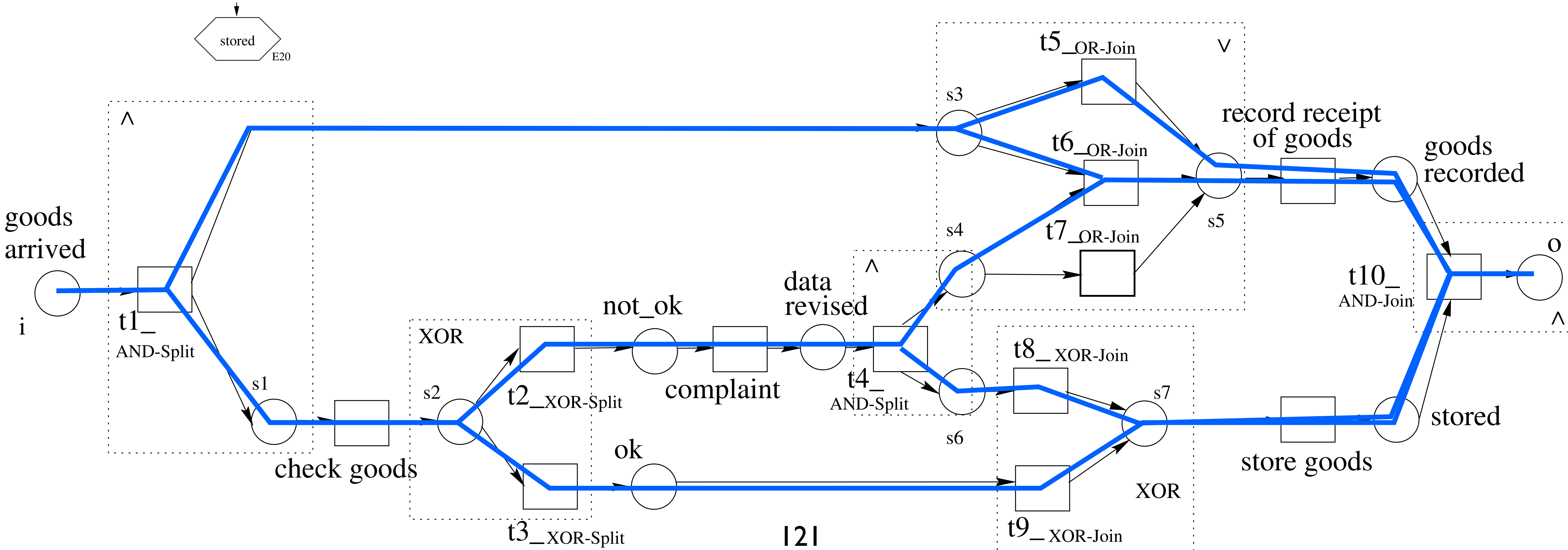
Relaxed sound?

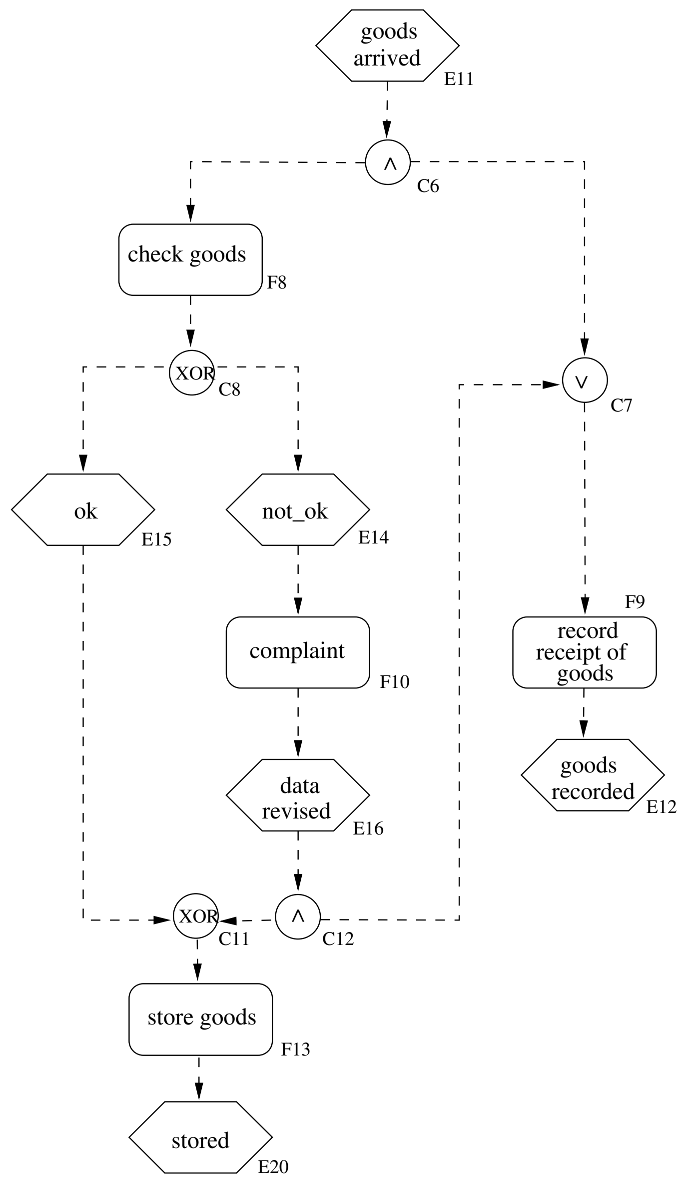


Example

Relaxed sound?



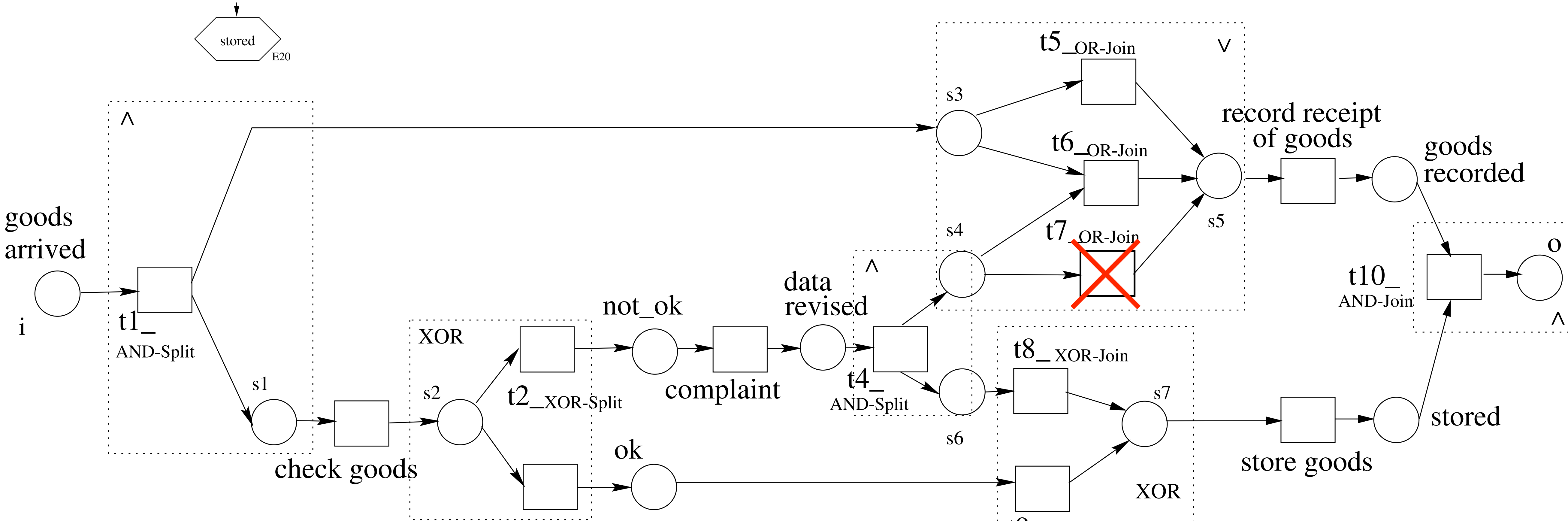




Example

Not relaxed sound (as WF net)!

But relaxed sound as EPC
(all nodes are covered
by some sound execution)



Pros and Cons

If the WF net is **not relaxed sound**:
there are transitions that are not part of a sound firing sequence

Hence their EPC counterparts need improvements

Relaxed soundness can be proven only by enumeration (of enough sound firing sequences)

No equivalent characterization is known that is more convenient to check

Open research problem…