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Inheritance of Dynamic Behavior in UML

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Motivation

- UML has become the standard object-oriented framework.
- Inheritance is one of the cornerstones of object orientation
- UML has at least four diagrams focusing on dynamic behavior / process modeling.
- Yet inheritance is typically restricted to static aspects.
- Frustration: Our work (with Twan Basten and Eric Verbeek) on inheritance has not been adopted by people working on UML.

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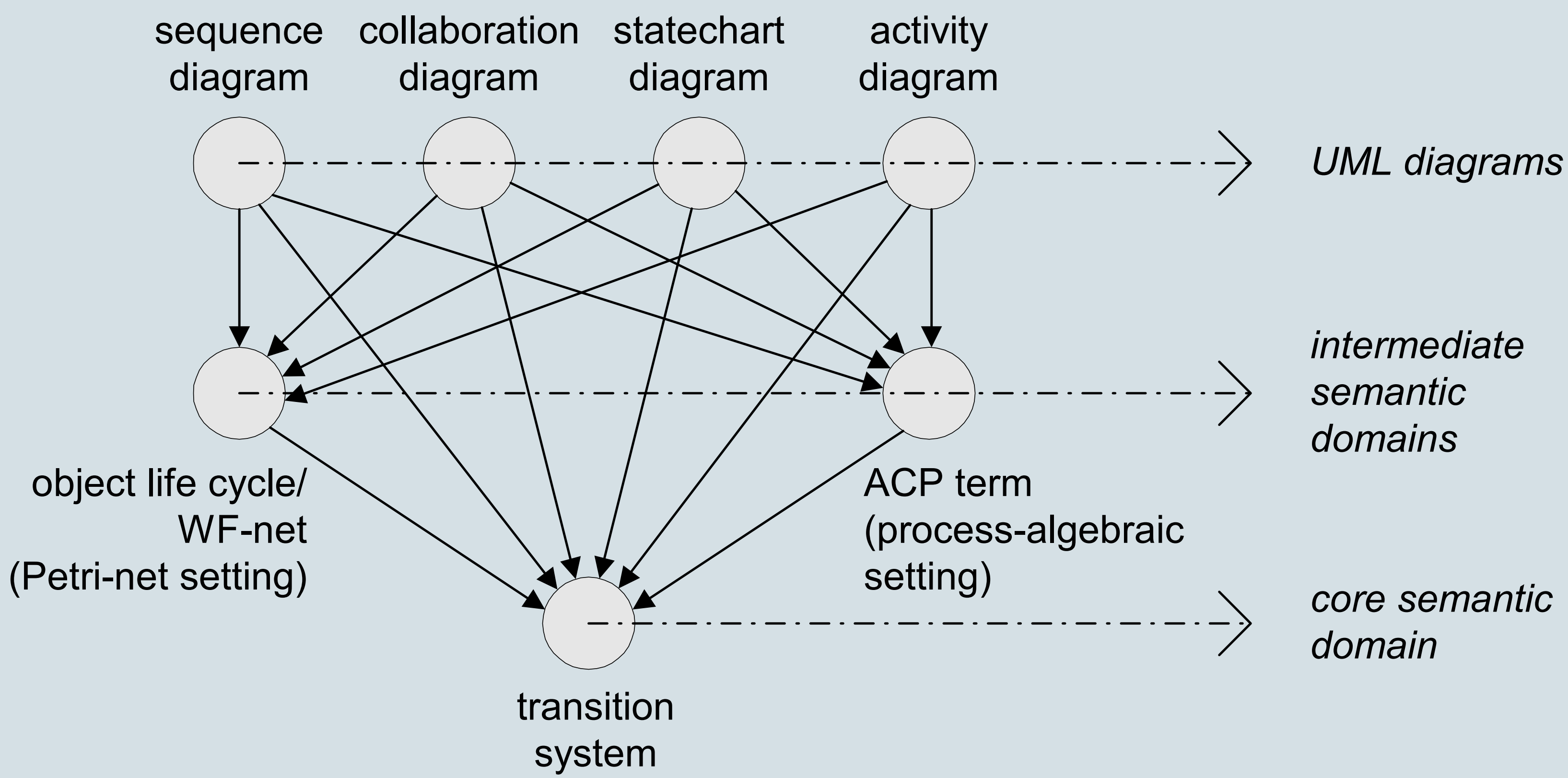
Approach [Engels et al. 2001]



- It is not our aim to provide formal semantics for UML.
- The mappings may be partial/abstractions.
- The intermediate domains are used for analysis purposes.

Inheritance of dynamic behavior

- When is a object life-cycle a subclass of another object life-cyle?
- Four notions of inheritance based on two orthogonal mechanisms.
- **Blocking**: *If it is not possible to distinguish the behaviors of x and y when only methods of x that are also present in y are executed, then x is a subclass of y.* (encapsulation)
- **Hiding:***If it is not possible to distinguish the behaviors of x and y when arbitrary methods of x are executed but when only the effects of methods that are also present in y are considered, then x is a subclass of y.* (abstraction)

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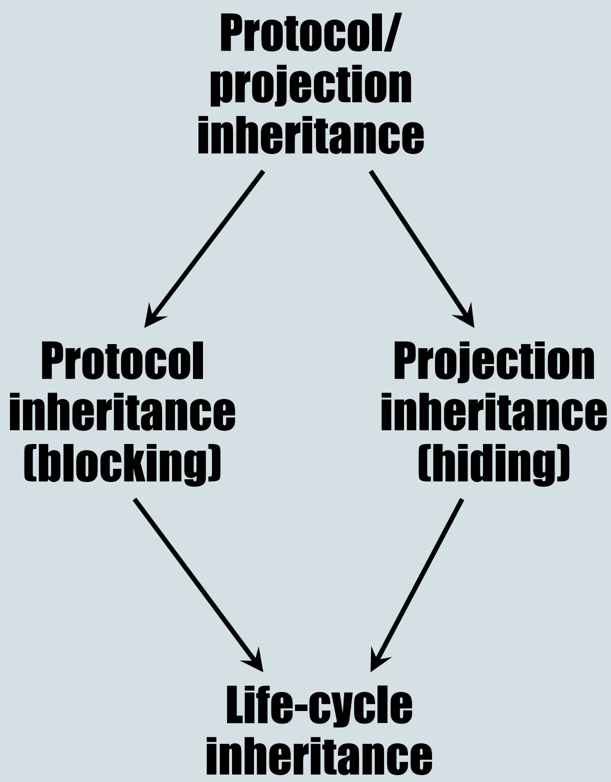
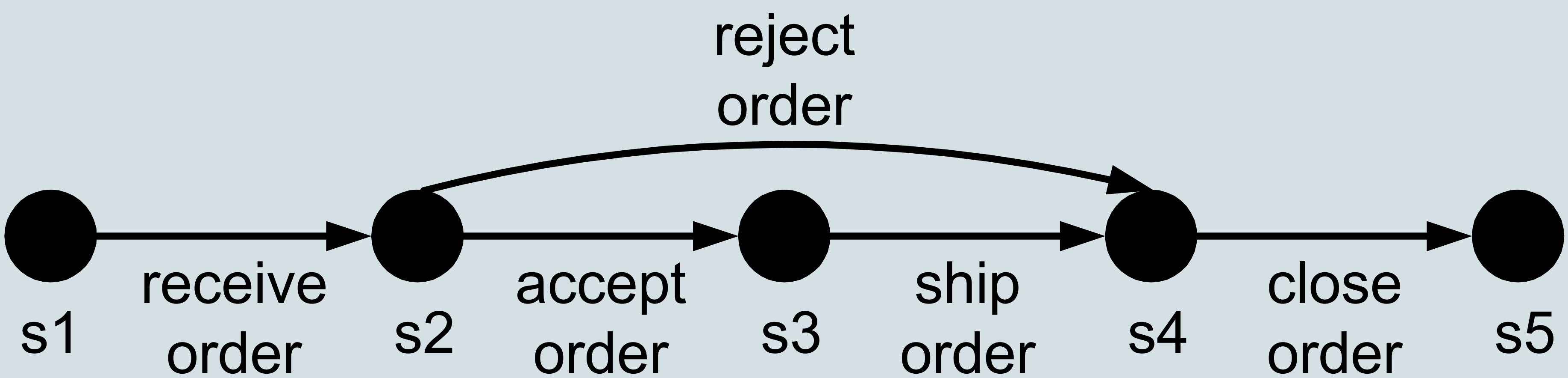
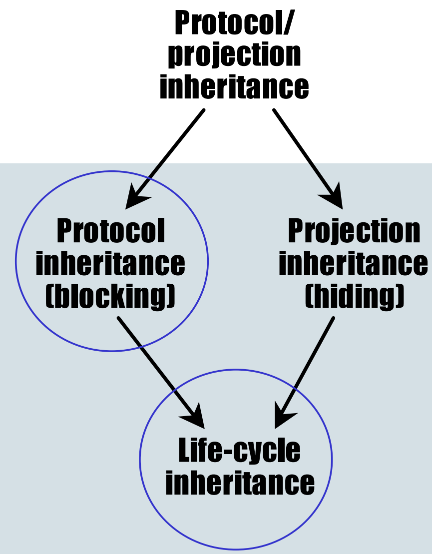
Four notions of inheritance



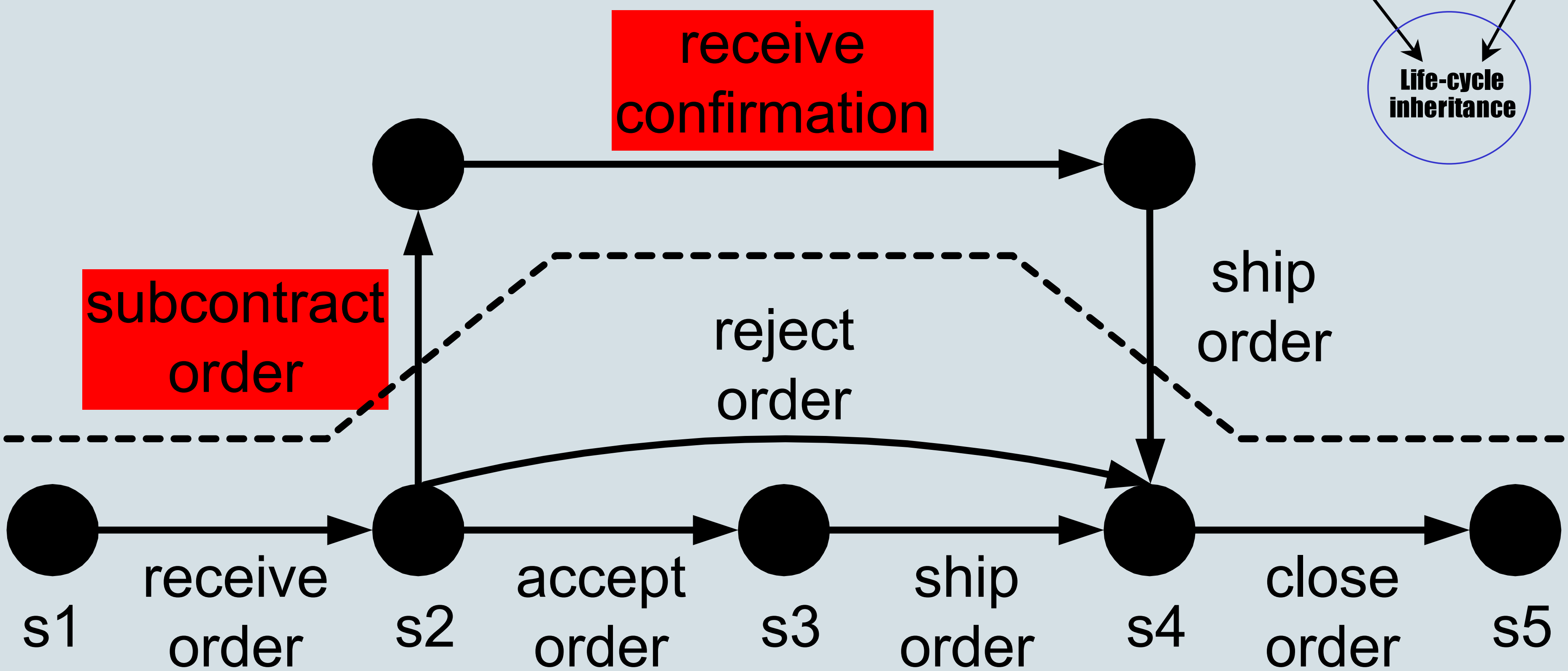
- Have been defined for the core semantic domain (labeled transition systems) and two intermediate semantic domains (Petri nets and ACP).
- We will illustrate the four notions of inheritance using the core semantic domain

Superclass TS1





Subclass TS2



Blocking: *If it is not possible to distinguish the behaviors of x and y when only methods of x that are also present in y are executed, then x is a subclass of y.*

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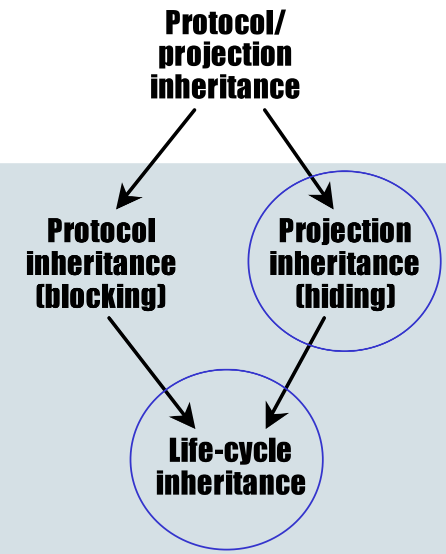
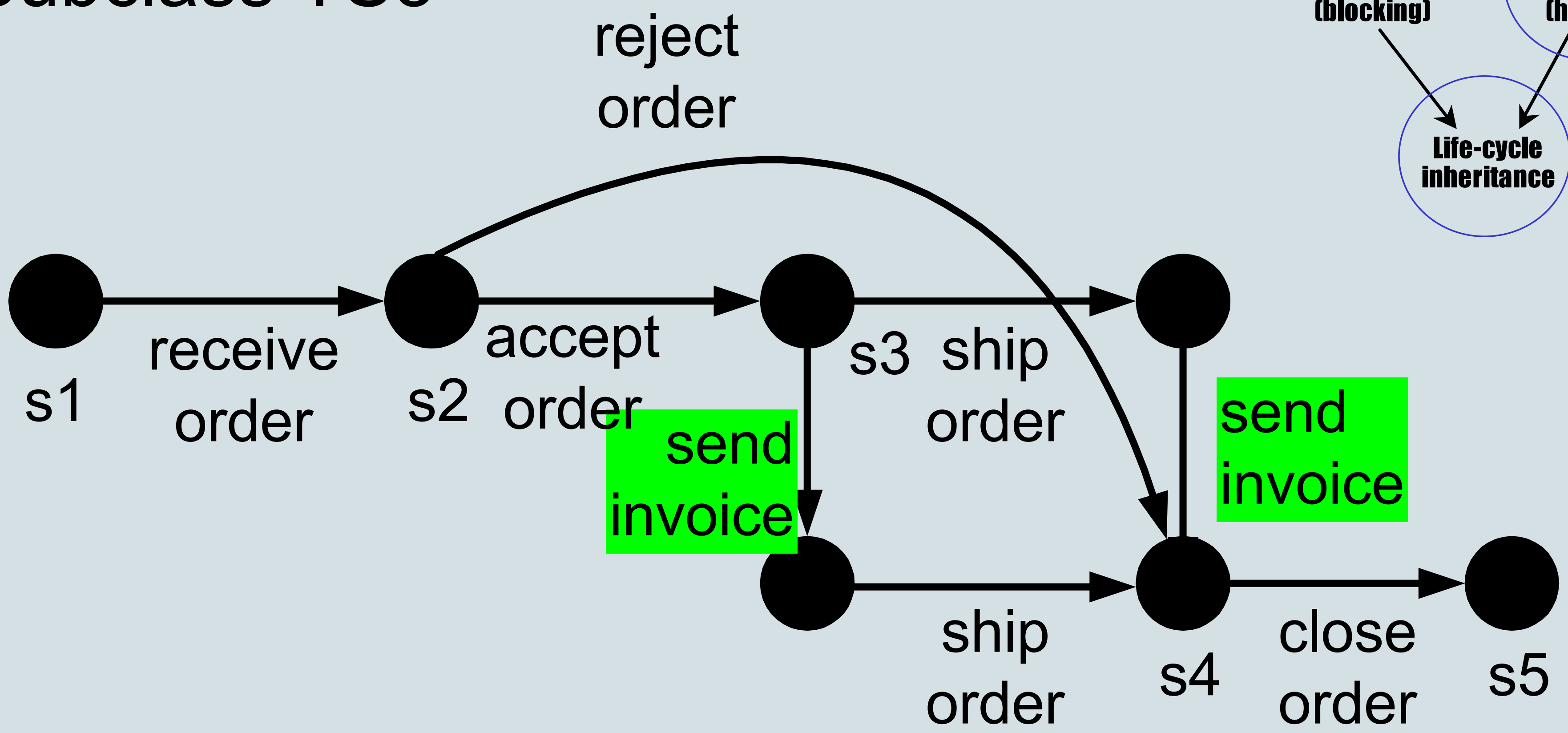


Subclass TS3



Hiding: *If it is not possible to distinguish the behaviors of x and y when arbitrary methods of x are executed but when only the effects of methods that are also present in y are considered, then x is a subclass of y.*

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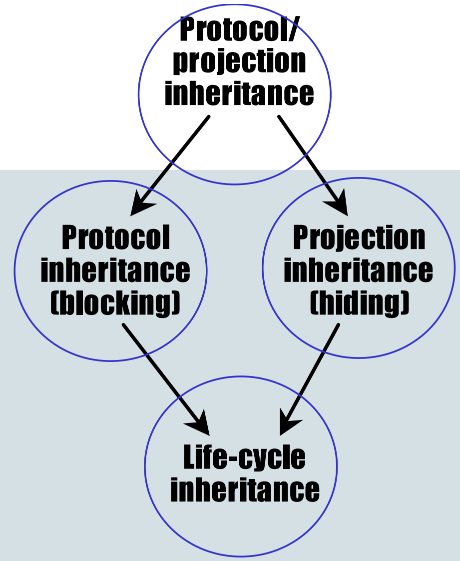
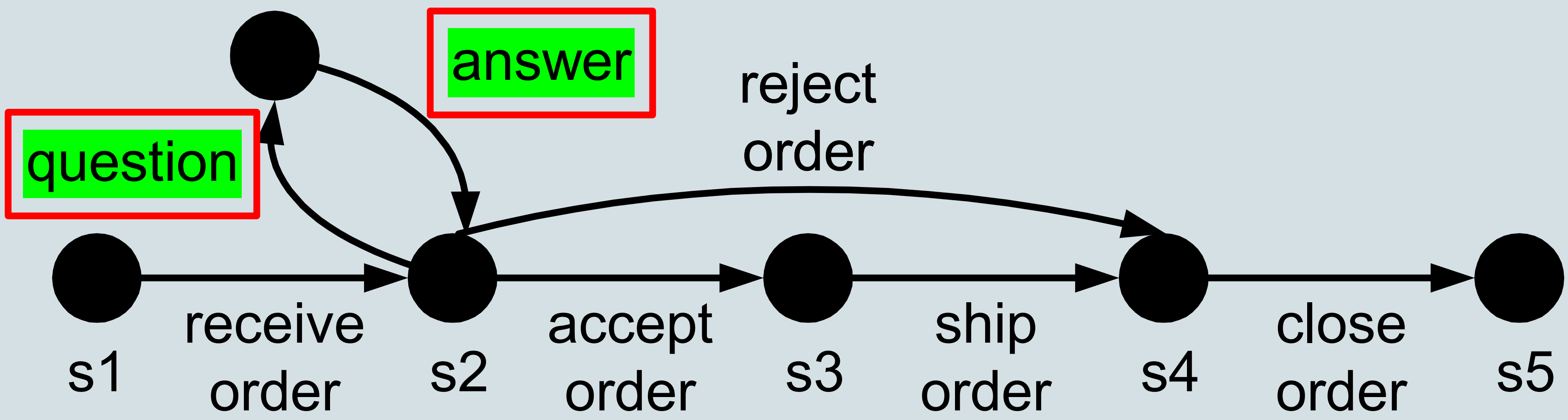
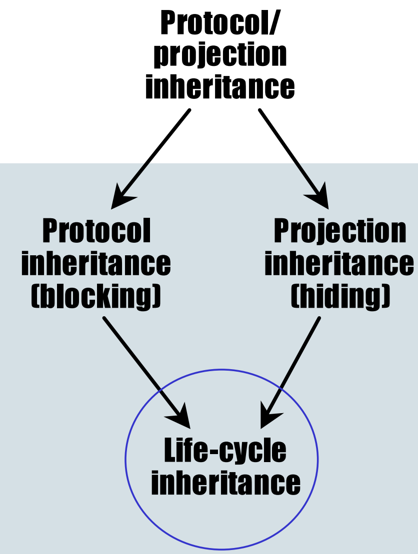
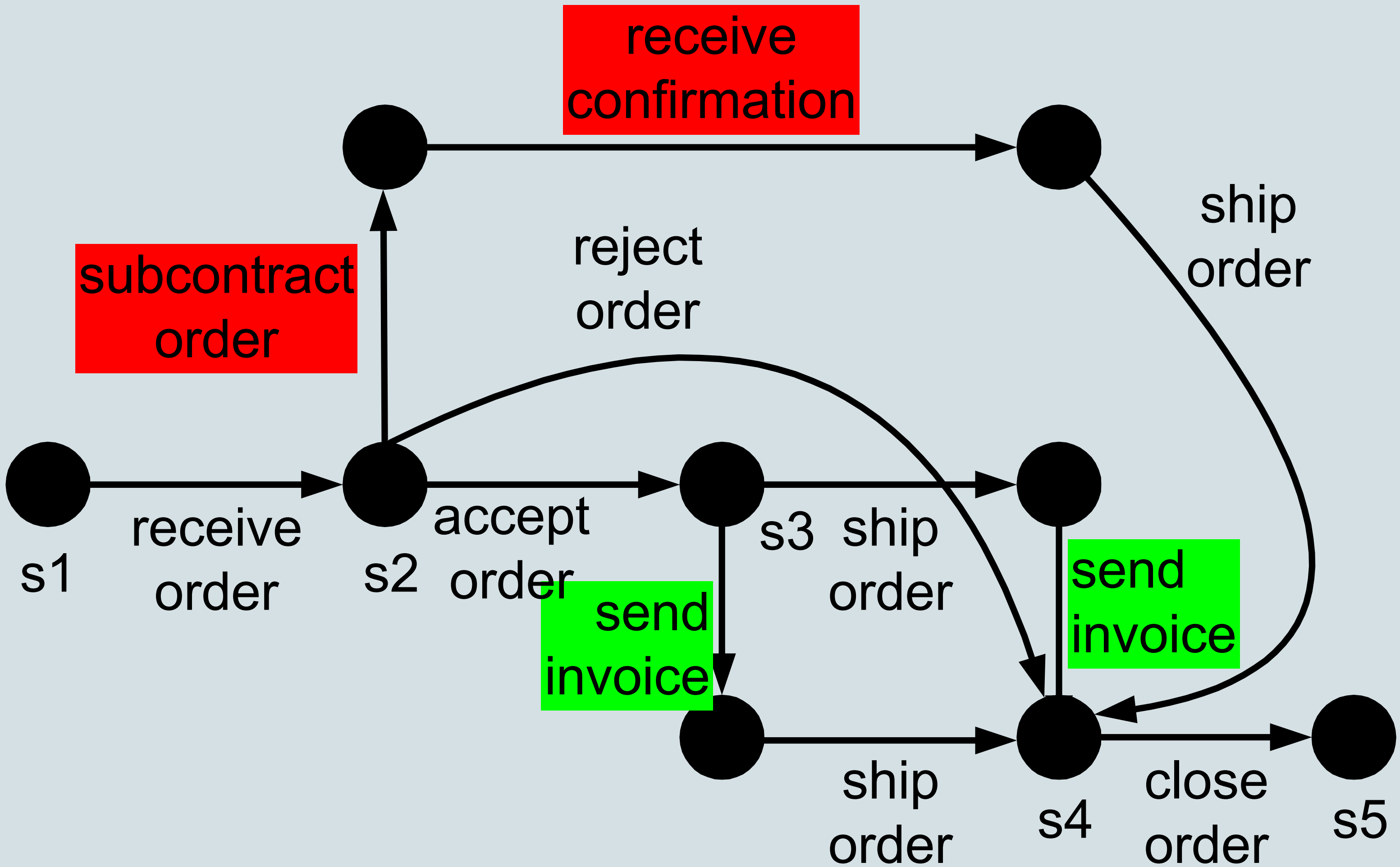
Subclass TS4





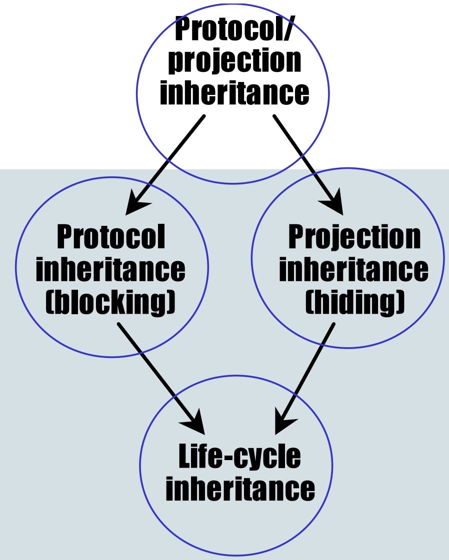
Subclass TS5



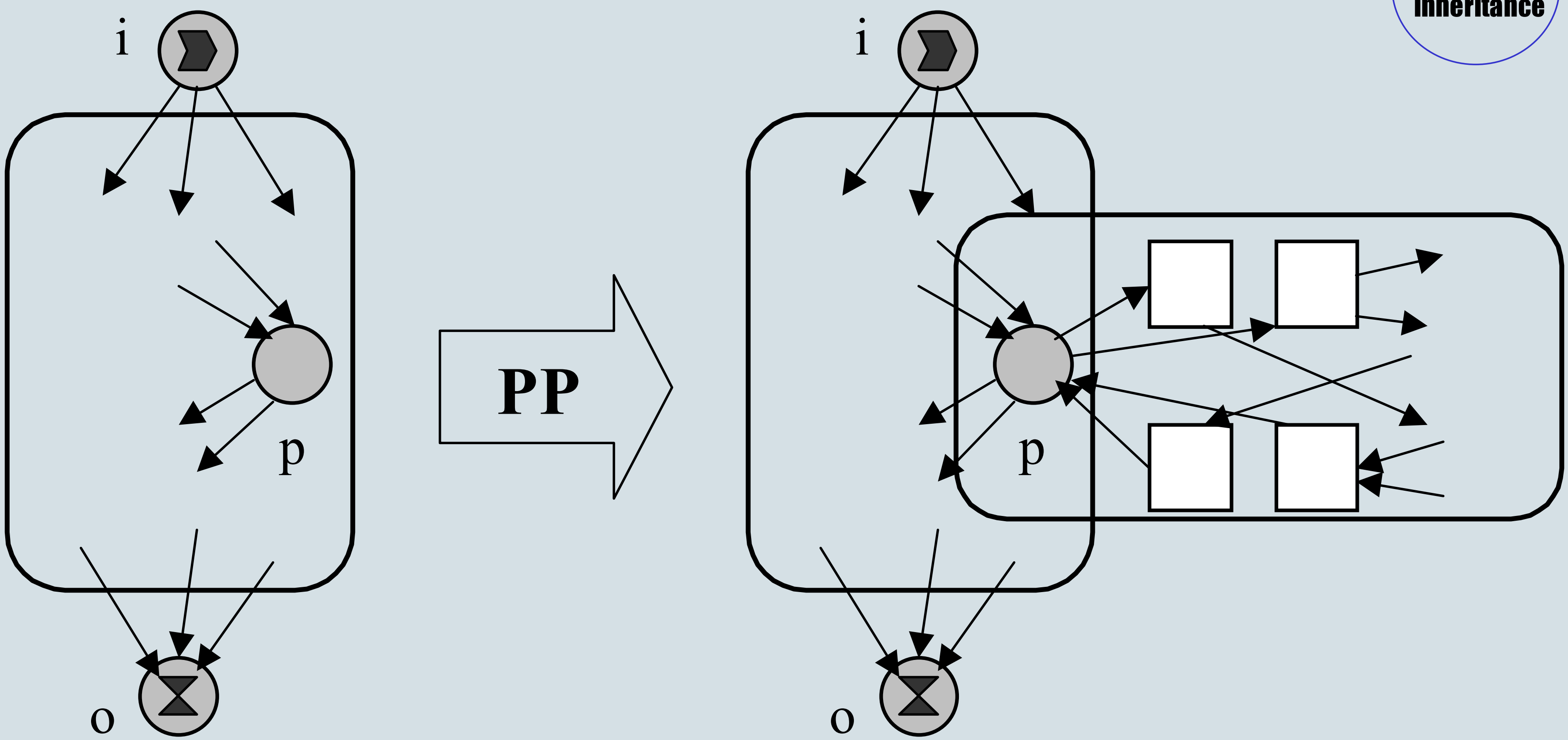


Inheritance preserving transformation rules

- Constructions which preserve one or more notions of inheritance, i.e., rules to transform a superclass into a subclass.
- The four basic rules PP, PT, PJ and PJ3 have been defined in both a Petri-net and a process-algebraic setting (i.e., both intermediate semantic domains considered).
- In this talk we show the rules in a Petri-net setting.
- The requirements for the rules can be checked locally.
- The transformation rules have been equipped with transfer rules to migrate objects from a superclass to a subclass and vice versa.



Transformation rule PP: adding loops



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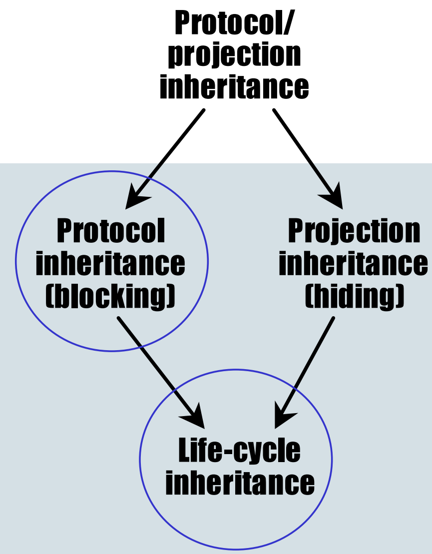
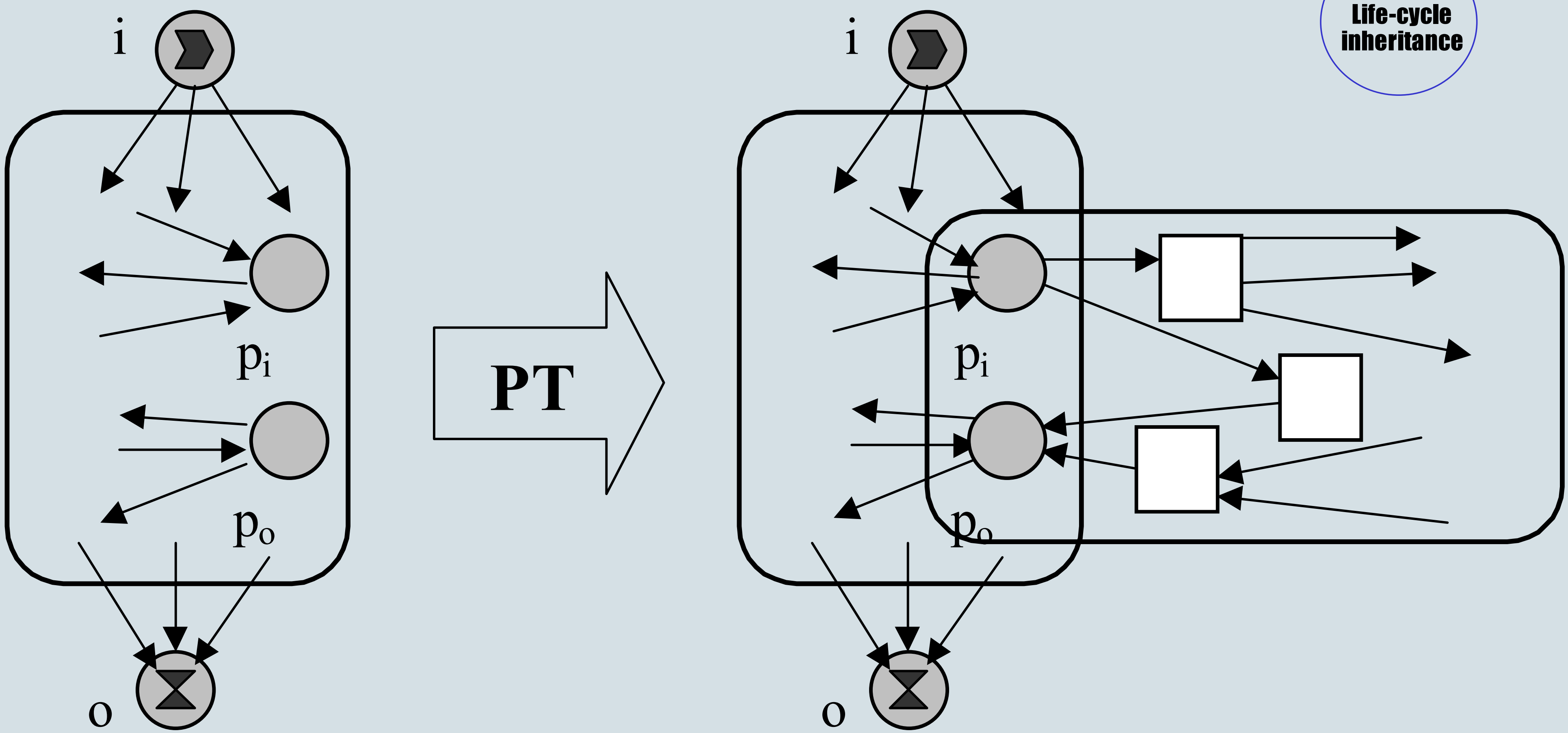
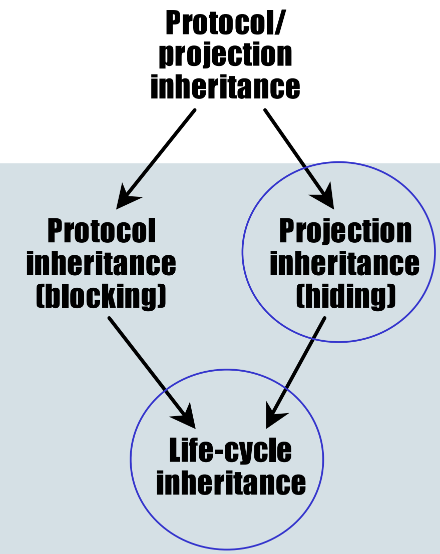
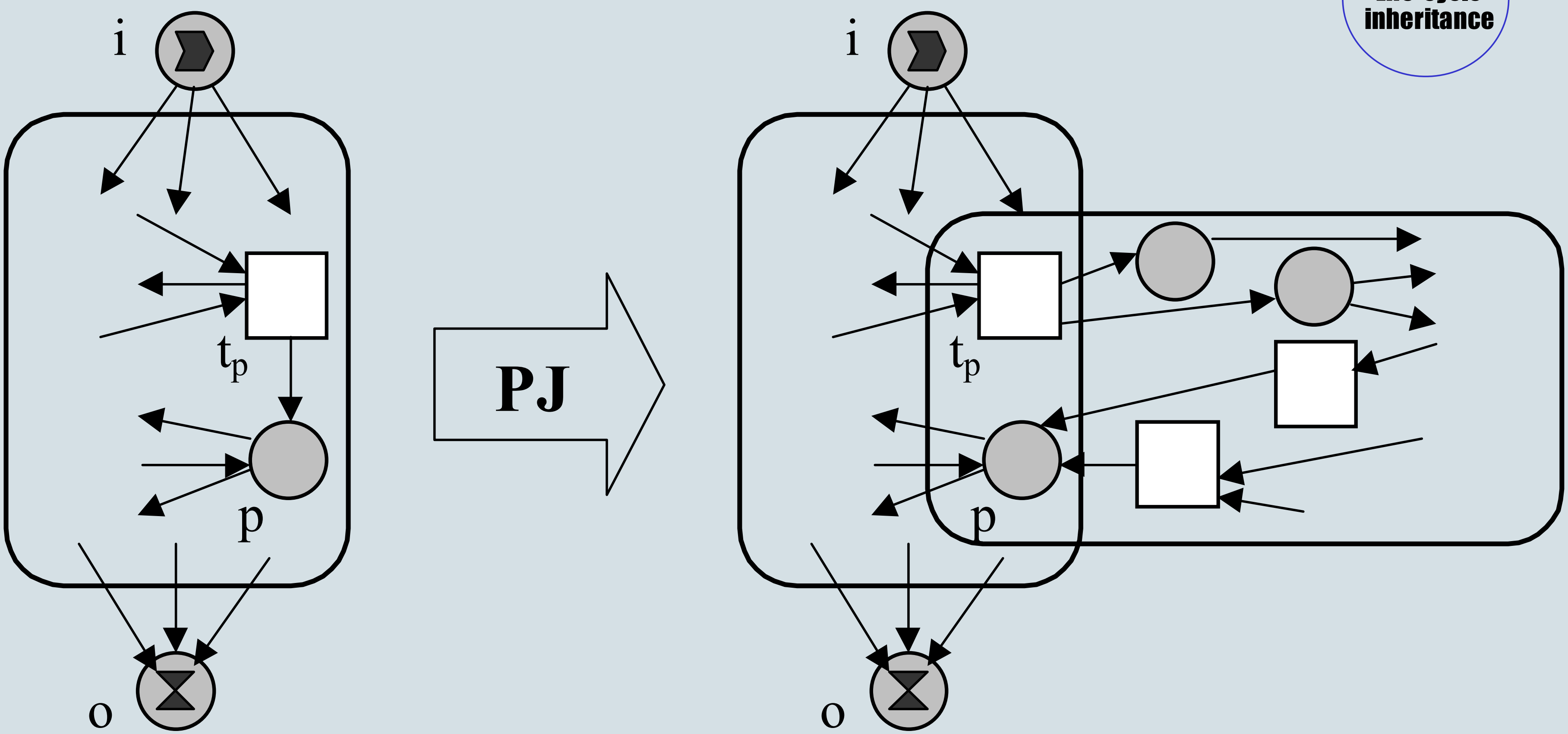
Transformation rule PT: adding alternatives





Transformation rule PJ: inserting steps





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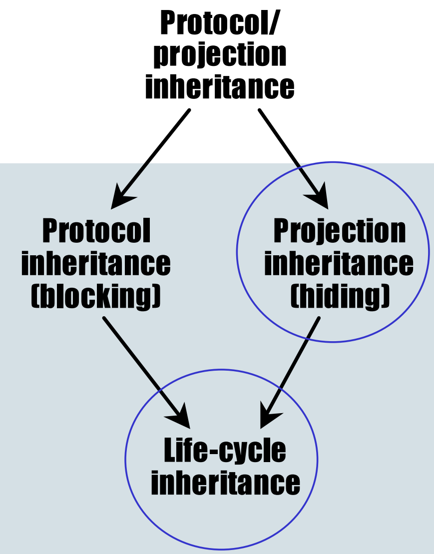
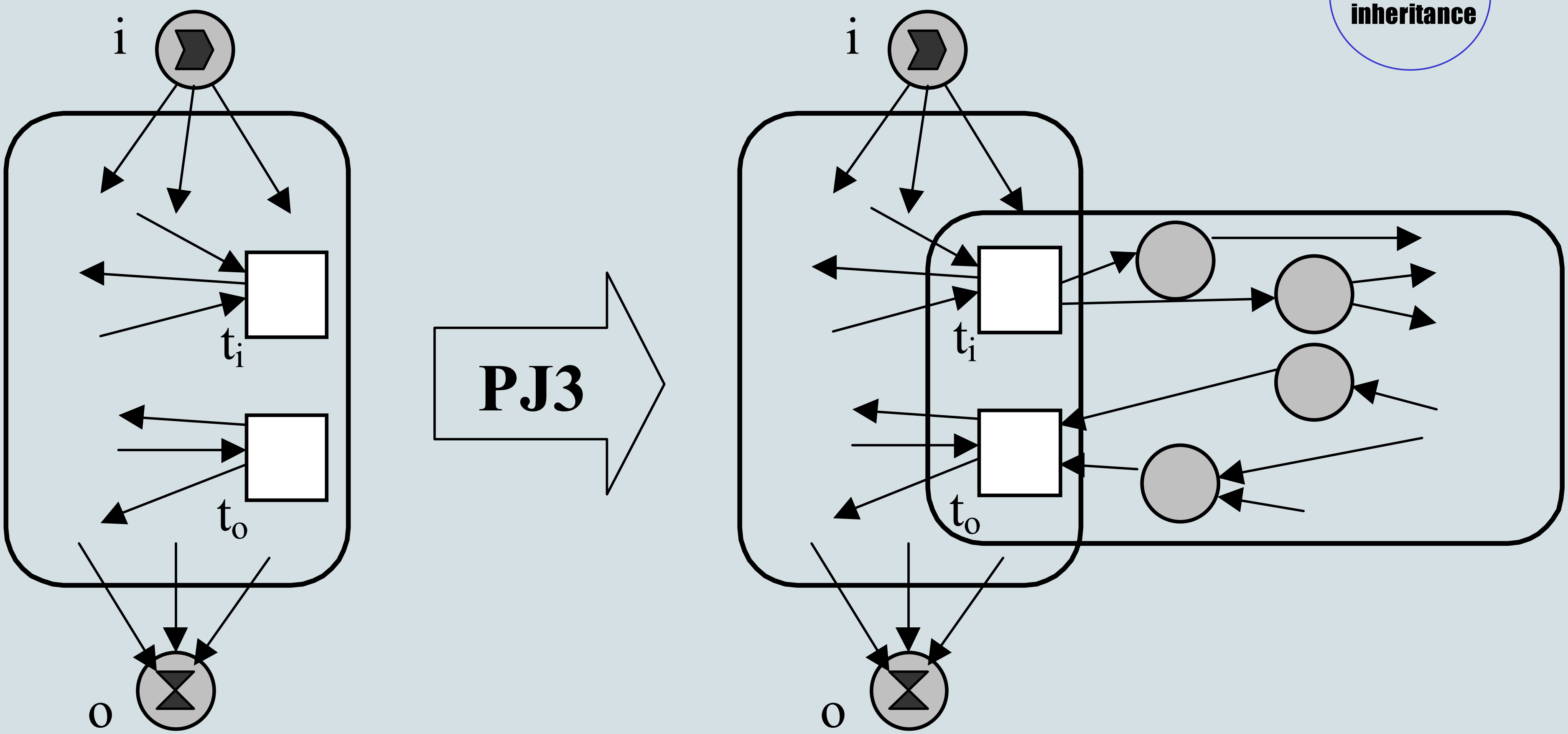
Transformation rule PJ3: add parallel behavior





Inheritance of behavior in UML

- The goal is to illustrate the four inheritance notions and the four transfer rules in the context of UML.
- The goal is NOT to provide a complete semantic mapping consistent with current standards.
- The four diagrams types that are relevant are:
  - Sequence diagrams
  - (Collaboration diagrams)
  - Statecharts diagrams
  - Activity diagrams

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Sequence diagrams

- *Constructs considered:* lifelines, messages (communications of type procedure call, asynchronous and return), activation and concurrent branching.
- *Not considered:* more advanced constructs such as iteration, conditional and timed behavior.
- *Semantic domains*: TS and PN (marked graphs).
- *Relevant notions of inheritance:* projection inheritance.
- *Relevant transformation rules:* PJ, PJ3 and PP.

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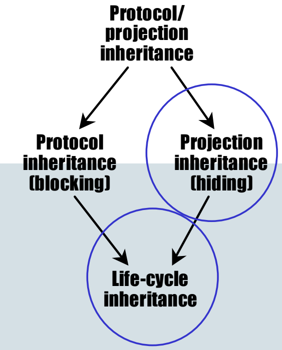
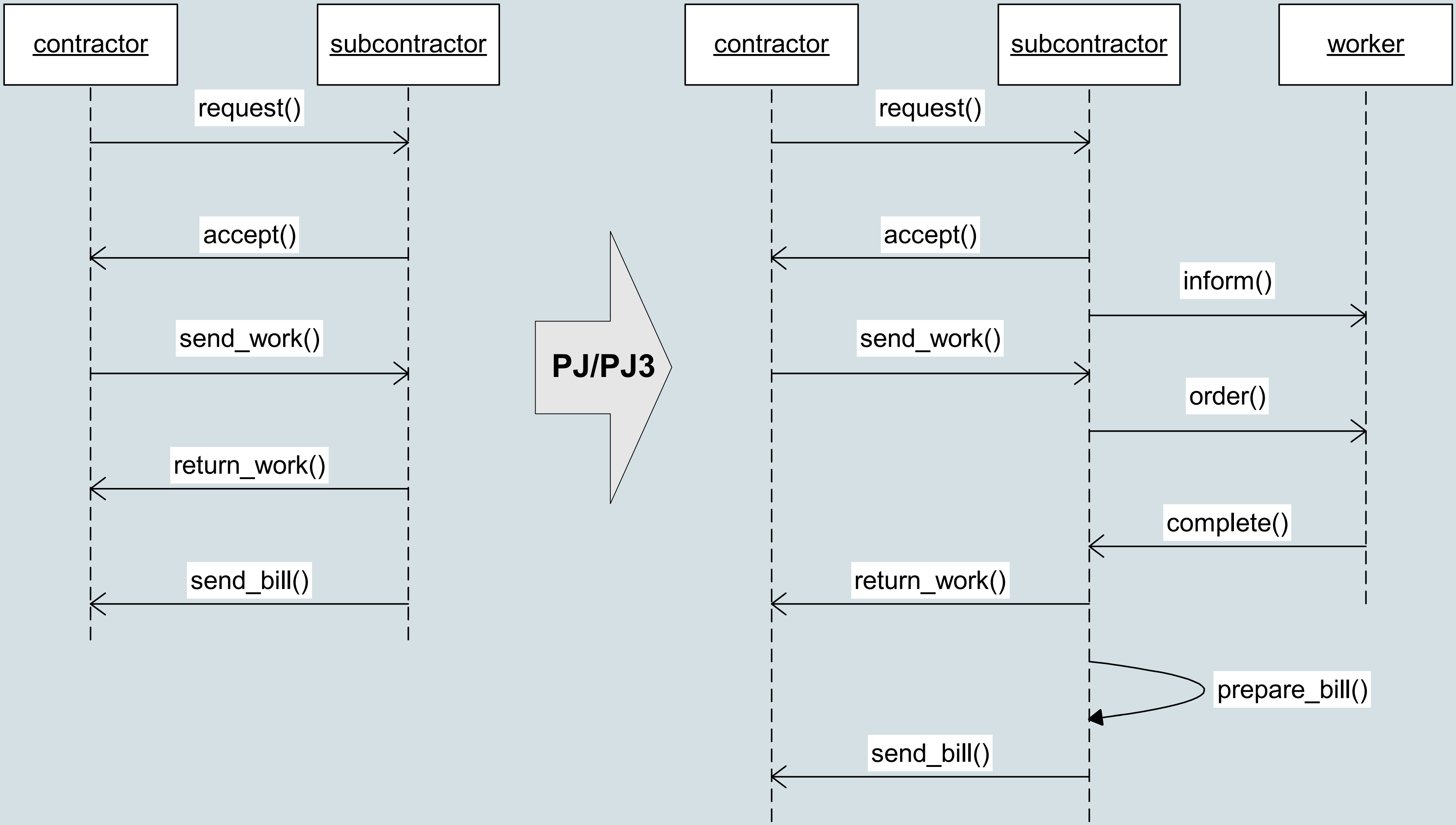
Example





Statechart diagrams

- *Constructs considered:* States, composite states, concurrent substates, transitions, compound transitions, etc.
- *Not considered:* data or time dependent behavior (e.g., abstraction from ECA rules).
- *Semantic domains*: TS, PA, and PN.
- *Relevant notions of inheritance:* all.
- *Relevant transformation rules:* all.

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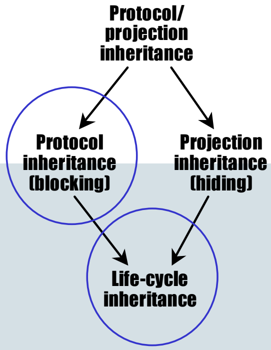
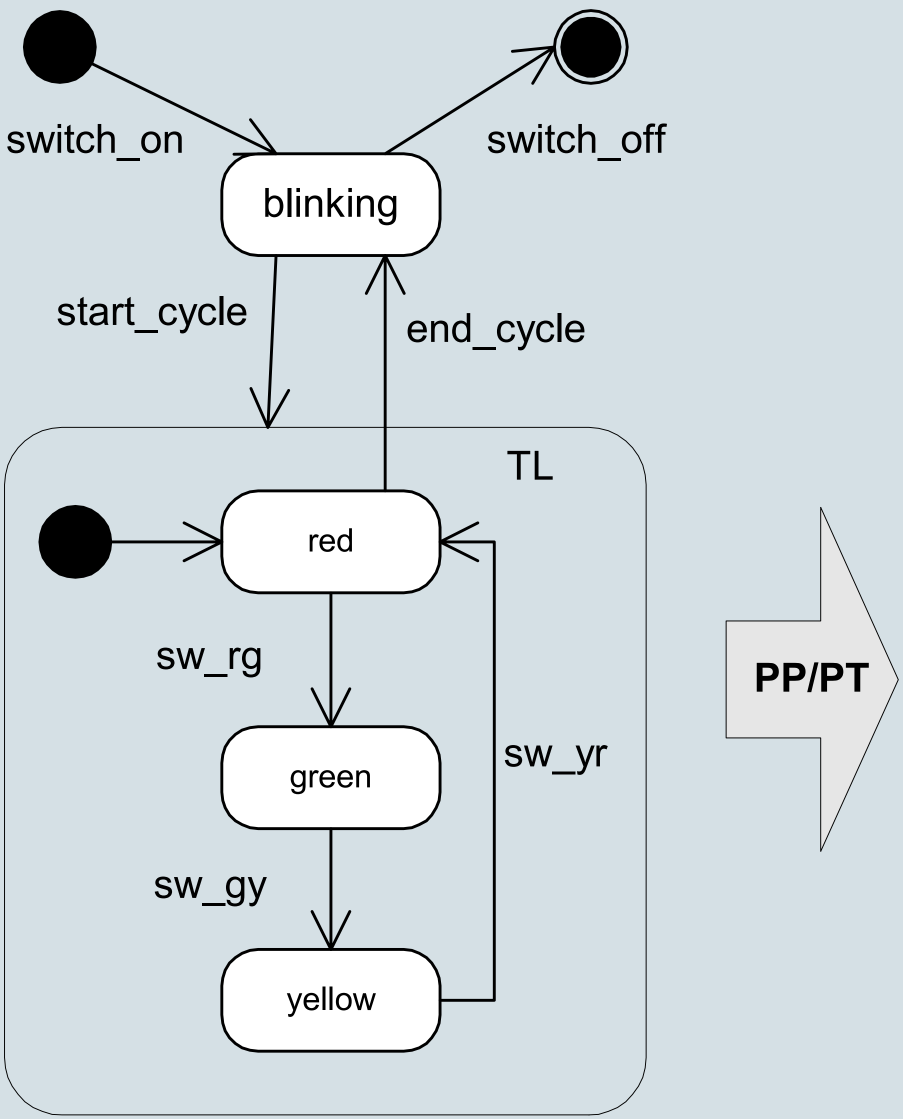
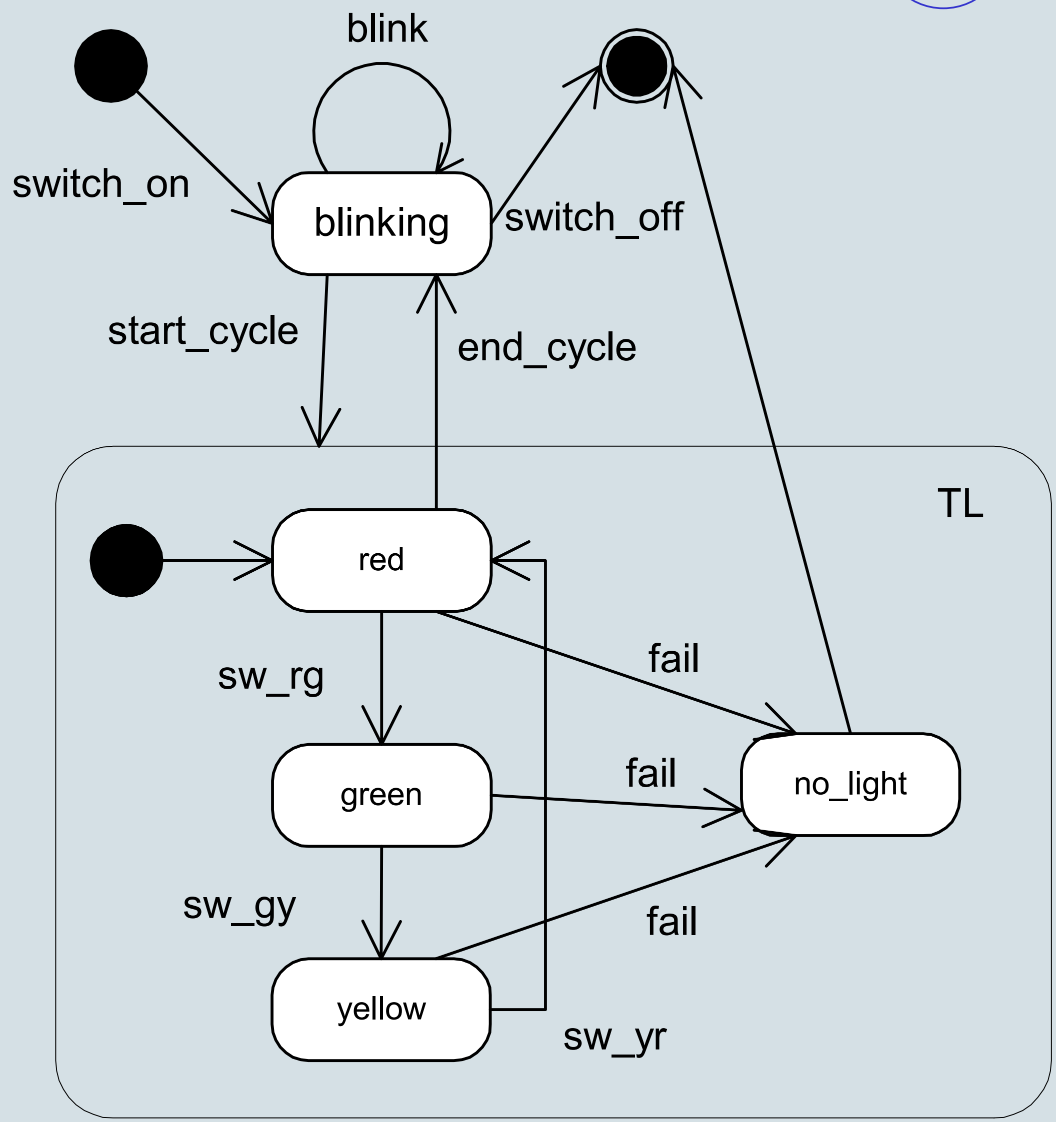
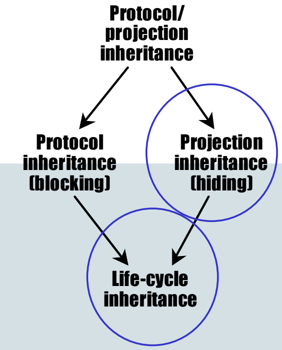


Example

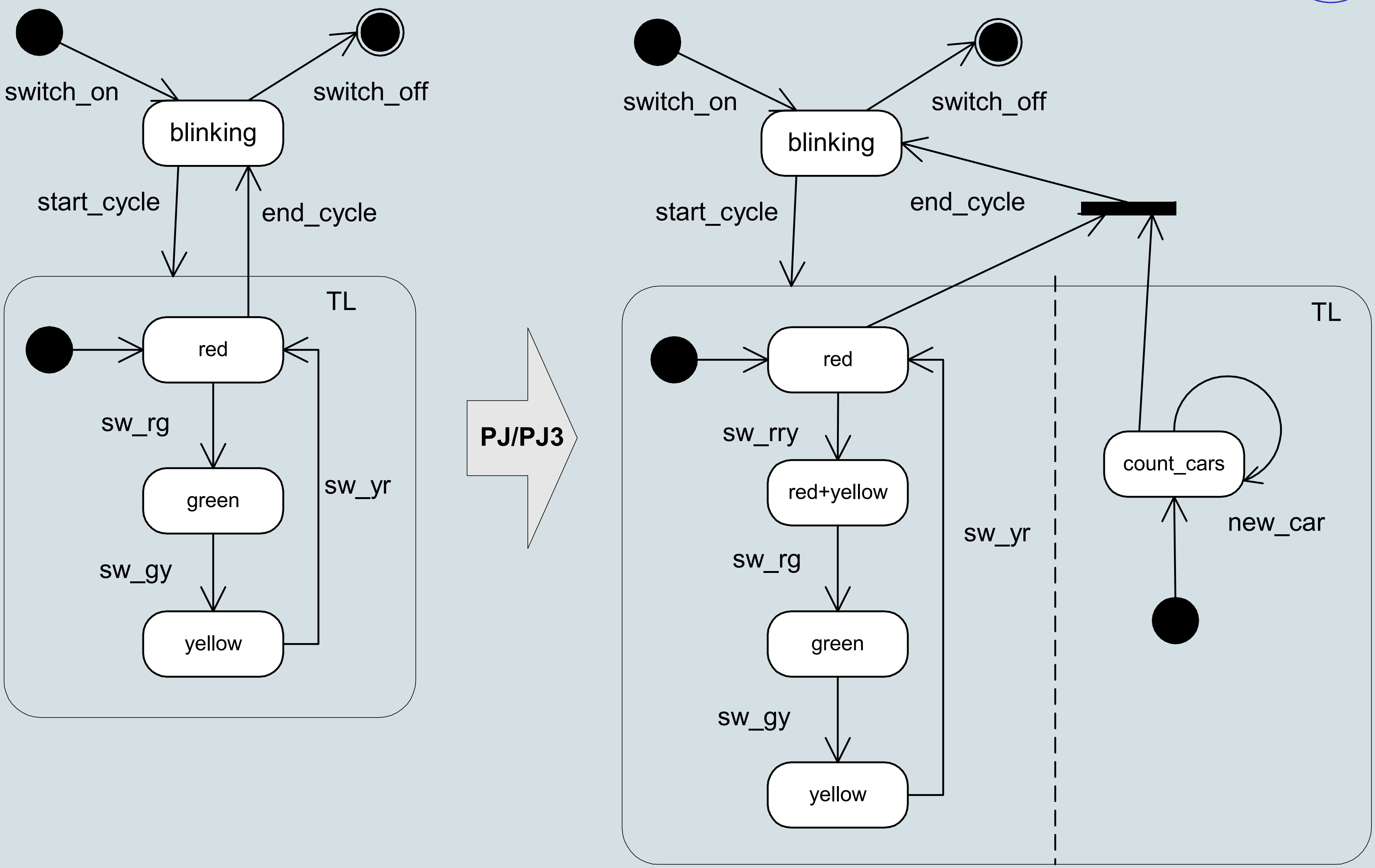




Example (2)



Protocol/ projection inheritance
Protocol inheritance (blocking)
Projection inheritance (hiding)
Life-cycle inheritance

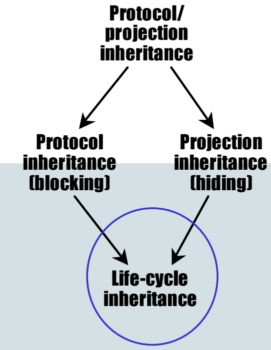


switch_on
switch_off
blinking
start_cycle
end_cycle
TL
red
sw_rg
green
sw_gy
yellow
sw_yr
PJ/PJ3
switch_on
switch_off
blinking
start_cycle
end_cycle
TL
red
sw_rry
red+yellow
sw_rg
green
sw_gy
yellow
sw_yr
count_cars
new_car

Activity diagrams

- *Constructs considered:* States, action states, decision/merge nodes, fork/join nodes, etc.
- *Not considered:* data or time dependent behavior (e.g., abstraction from ECA rules).
- *Semantic domains*: TS, PA, and PN.
- *Relevant notions of inheritance:* all.
- *Relevant transformation rules:* all.

Example


Protocol/ projection inheritance
Protocol inheritance (blocking)
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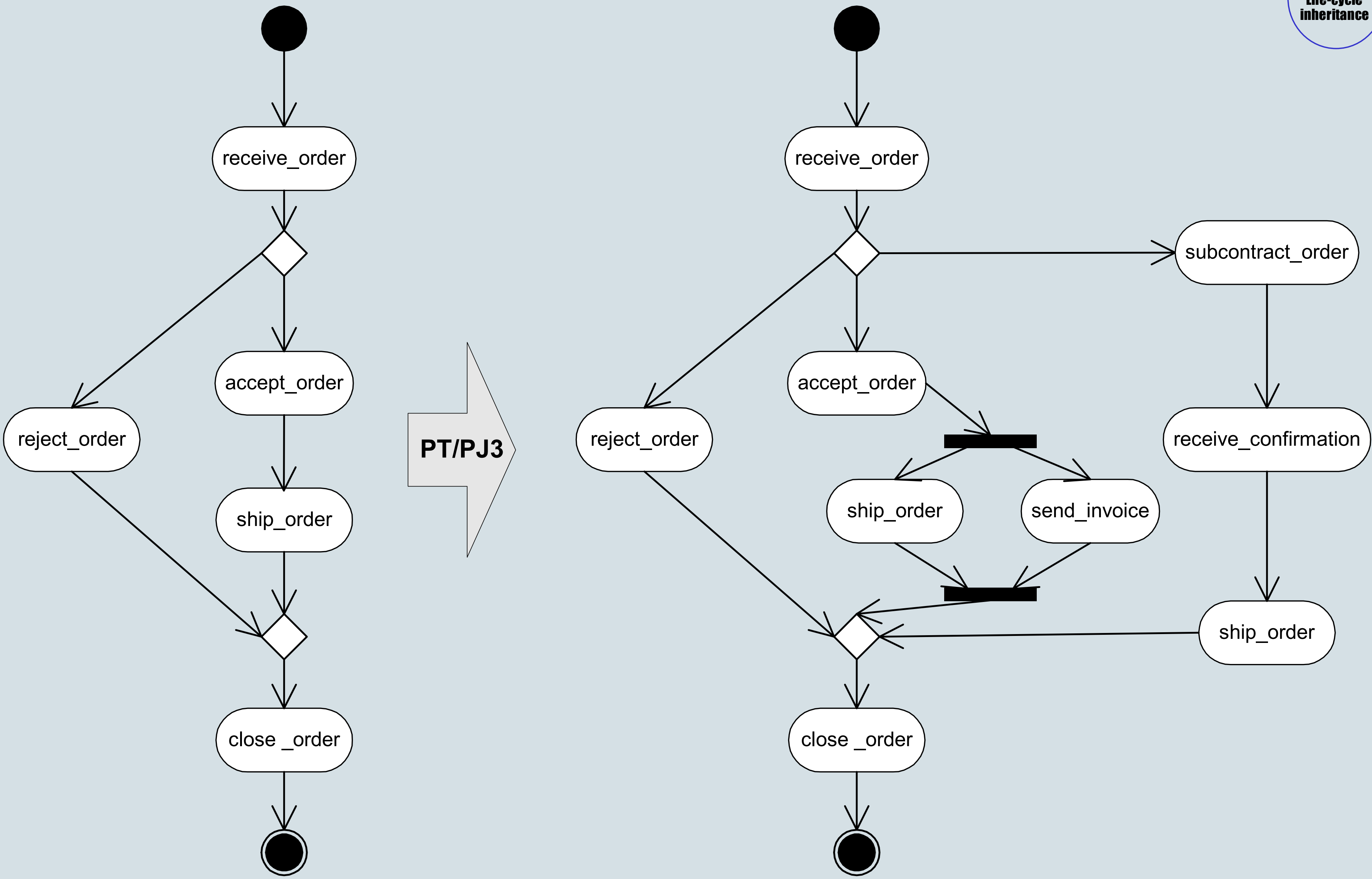
receive_order
accept_order
reject_order
ship_order
close _order
PT/PJ3
receive_order
subcontract_order
accept_order
reject_order
receive_confirmation
ship_order
send_invoice
ship_order
close _order

Conclusion

- Four definitions of inheritance have been illustrated using the core semantic domain.
- Four transformation rules haven been illustrated using one of the intermediate semantic domains.
- To illustrate the applicability of these notions in the context of UML, examples have been given for sequence, statechart, and activity diagrams.

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