Manufacturing Engineering

Introduction to the Process Specification Language

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NIST

“PSL” stands for …

- … Process Specification Language,
- ... but not in the sense of a process model or programming language.
- Should be called:
  - Process Semantics Language.
  - Process Constraint Language.
- PSL enables:
  - Describing what actually happens when a process specification executes.
  - Writing constraints on processes.

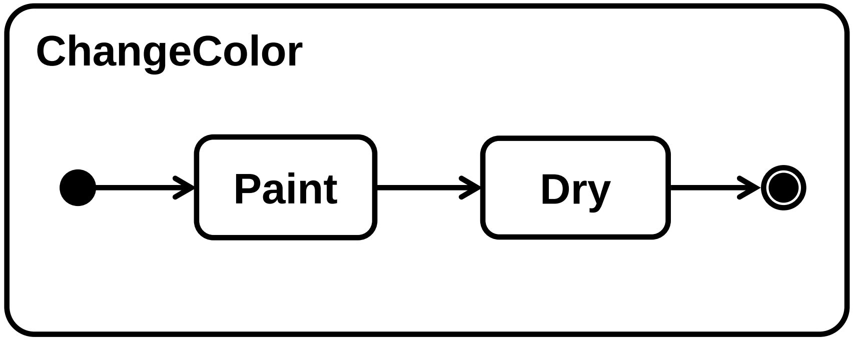
PSL Background

- Based on long period of research:
  - Situation calculus.
  - Process Interchange Format (PIF).
  - Enterprise modeling.
- Applied to scheduling, process modeling, process planning, production planning, simulation, project management, workflow, business process reengineering, vehicle navigation, semantic interoperability.
- ISO 18629, full international standard.
- Basis of Semantic Web Services (SWSL) at W3C.

- “Some philosophical problems from the standpoint of artificial intelligence,” McCarthy, J., Hayes, P., in Meltzer B, Michie D (eds) Machine Intelligence 4, Edinburgh University Press, Edinburgh, pp 463–502, 1969.
- Knowledge in Action: Logical Foundations for Specifying and Implementing Dynamical Systems, Reiter, R., MIT Press, 2001.
- The Process Interchange Format Project, http://ccs.mit.edu/pif.
- “The TOVE Project: A Common-sense Model of the Enterprise, Industrial and Engineering Applications of Artificial Intelligence and Expert Systems,” Fox, M., in Belli, F., Radermacher, F. (eds.), Lecture Notes in Artificial Intelligence # 604, Springer-Verlag, pp 25–34, 1992.
- “Enterprise Modelling,” Fox, M., Gruninger, M., AI Magazine, AAAI Press, pp. 109–121, Fall 1998.
- Semantic Web Services Framework (SWSF), W3C, http://www.w3.org/Submission/2005/07/, 2005.

Process Models

- UML 2:



(or UML repository)

- BPEL:

```
<process name=“ChangeColor”>
   <sequence>
     <invoke operation=“Paint”></invoke>
     <invoke operation=“Dry”></invoke>
   </sequence>
 </process>
```

- C:

```
void ChangeColor
{ Paint();
  Dry();
}
```

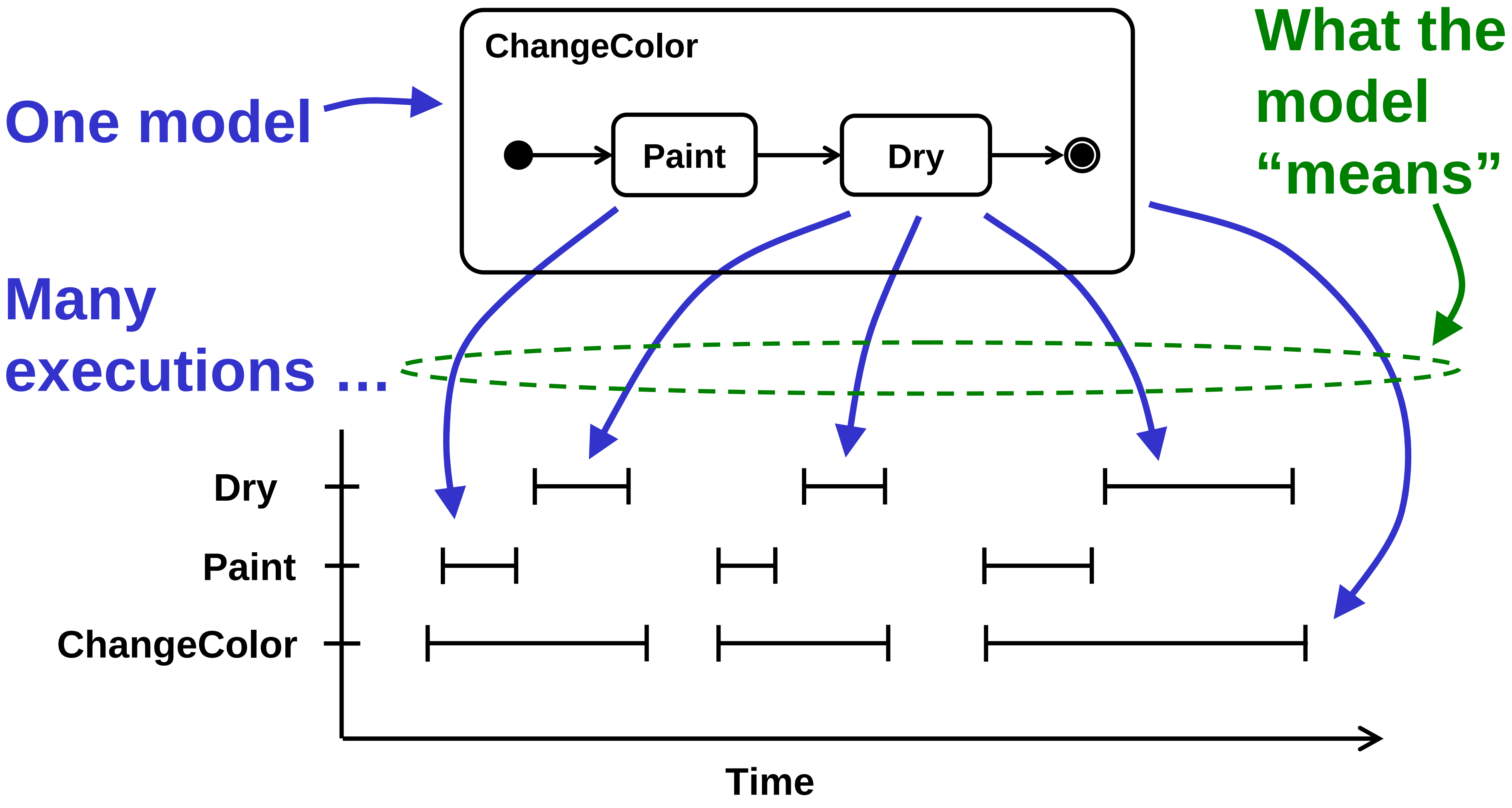
What Happens?

- Does Dry start only after Paint finishes?
  - Yes, unless Paint is invoked asynchronously.
- Does Dry happen everytime Paint does?
  - Not necessarily, the model is referring only to the ChangeColor process.
- These questions are about the actual execution of the process.
  - Which steps start and stop when.
  - What the process model “means”.

Capture the Meaning

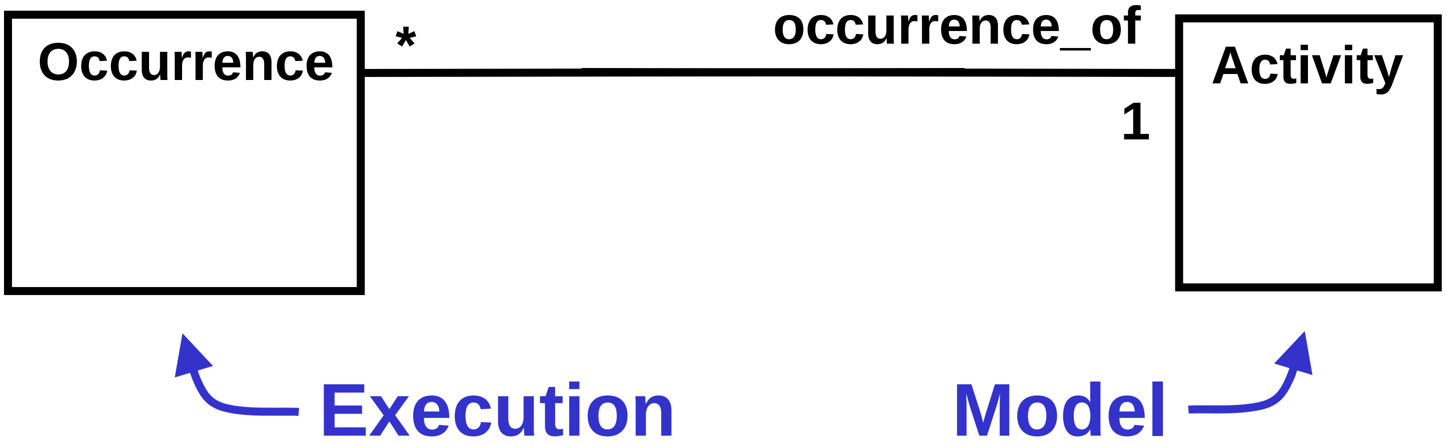
- How do we know what the model means?
  - Read the language documentation.
  - Execute the model on a reference implementation.
  - Ask somebody.
- Humans eventually figure it out, but what about the tools?
  - They can’t read documentation, experiment with implementations, or ask anyone.
- Need a way to express the meaning of process models in a way tools can understand.

Model vs. Execution



- … each satisfying the constraints of the model.

PSL Model of Execution



- **Occurrence is an execution of an Activity**
  - **for example, Paint executed at 10:22am ET 9/1/2003 at factory 1.**

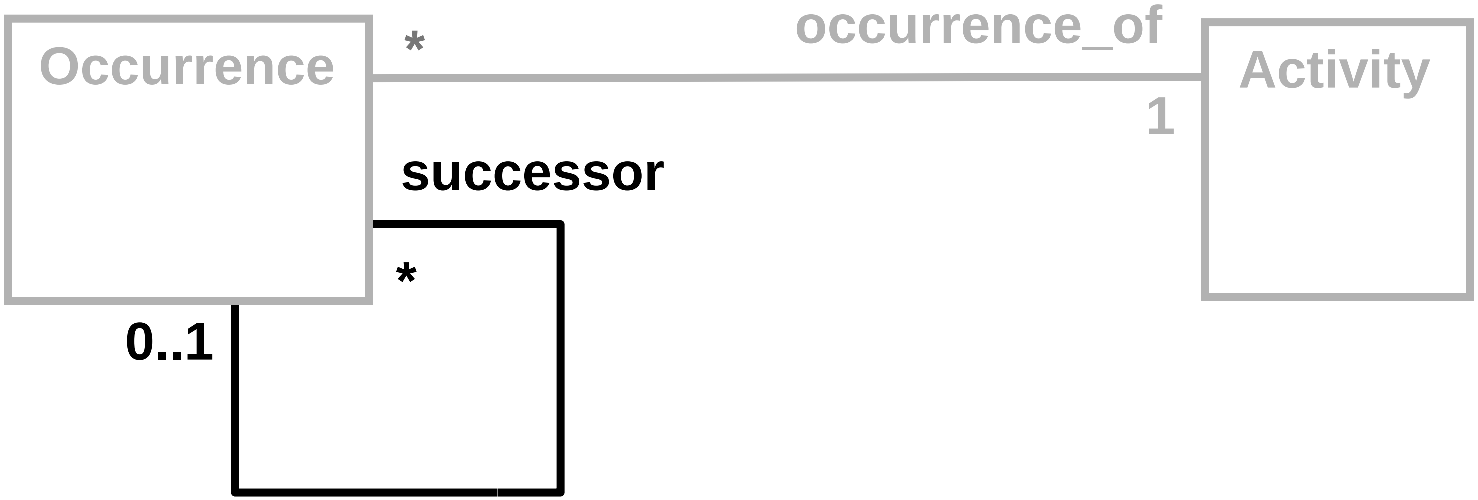
PSL Model of Execution

- **PSL is defined in the Common Logic Interchange Format (CLIF)…**
- **… but could be OCL or other FOL language.**

```
(forall (?occ ?a)
   (if (occurrence_of ?occ ?a)
       (and (activity_occurrence ?occ)
            (activity ?a))))
(forall (?occ)
   (if (activity_occurrence ?occ)
       (exists (?a)
          (and (activity ?a)
               (occurrence_of ?occ ?a)))))
(forall (?occ ?a1 ?a2)
   (if (and (occurrence_of ?occ ?a1)
            (occurrence_of ?occ ?a2))
       (= ?a1 ?a2)))
```

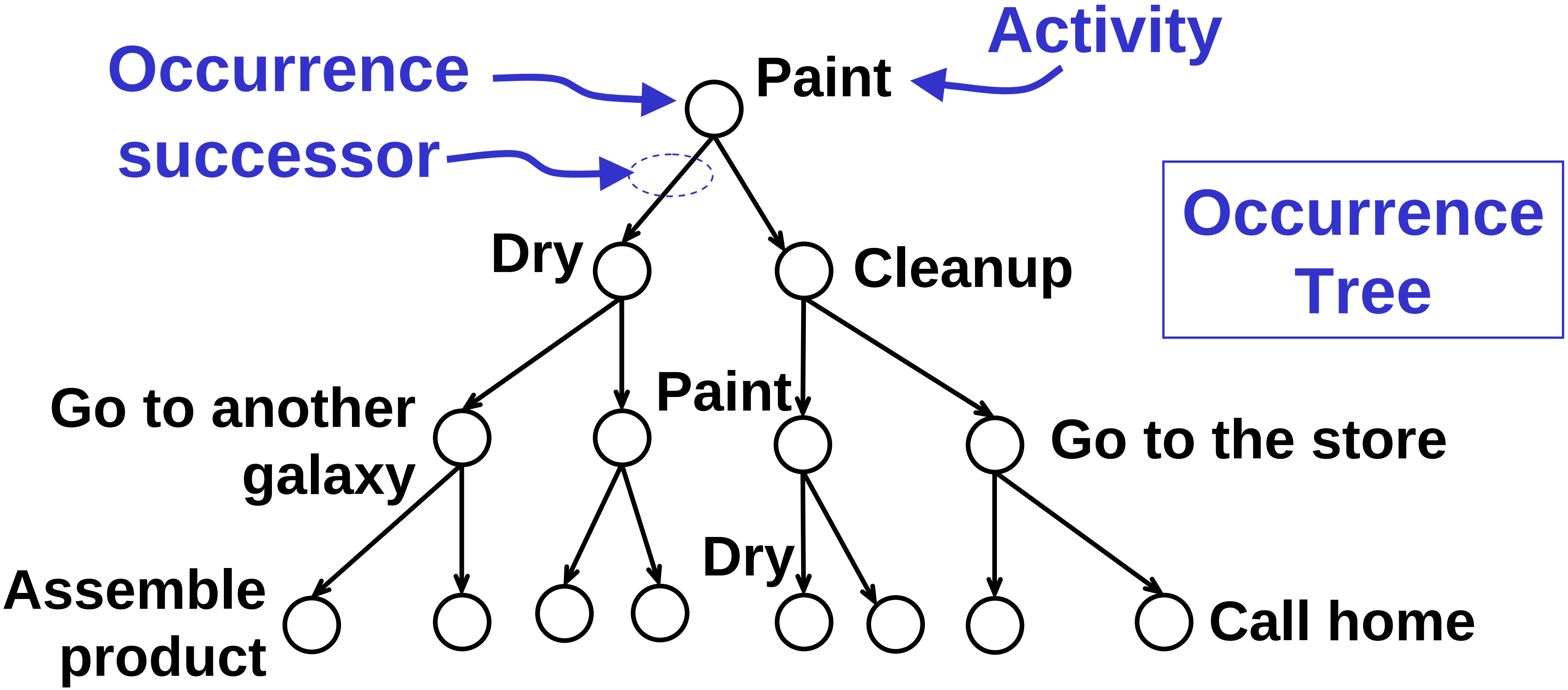
- "Common Logic (CL) - A Framework for a Family of Logic-Based Languages," ISO, WG2, SC32, IEC JTC1, http://standards.iso.org/ittf/PubliclyAvailableStandards/c039175_ISO_IEC_24707_2007(E).zip, October 2007.
- "Object Constraint Language," OMG, http://doc.omg.org/formal/06-05-01, May 2006.

PSL Model of Execution



- Executions happen one after another.
- Notice the multiplicities:
  - Occurrence has multiple successors, one for each (theoretically) possible next occurrence.

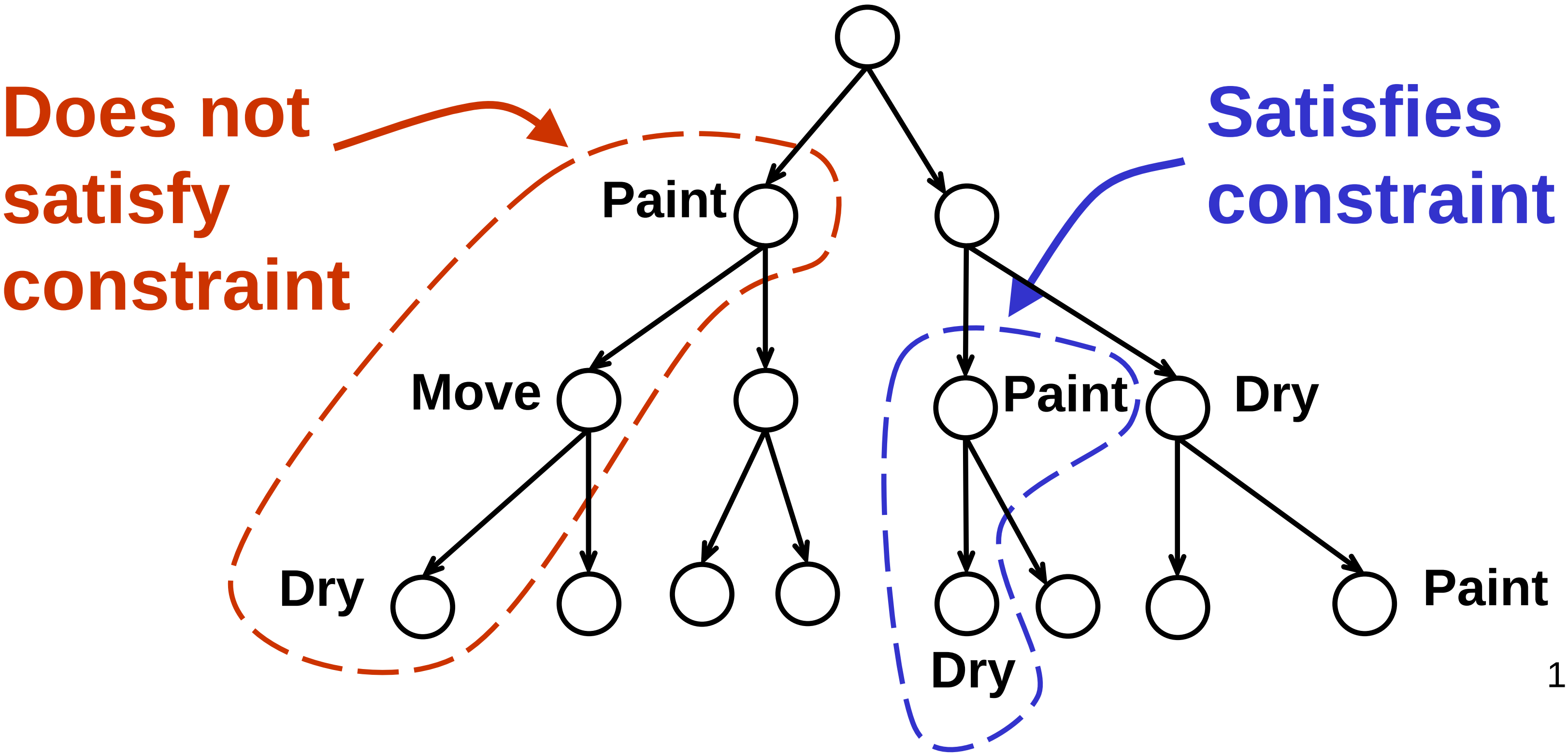
Anything Can Happen



- Tree of all possible execution sequences, including
  - not physically possible.
  - not specified by the user.
- Not stored anywhere, just referred to by constraints.

Rules as Occurrence Constraints

- Specify which parts of the occurrence tree are “legal”.
- Example rule: drying immediately follows all painting.



Does not satisfy constraint

Satisfies constraint

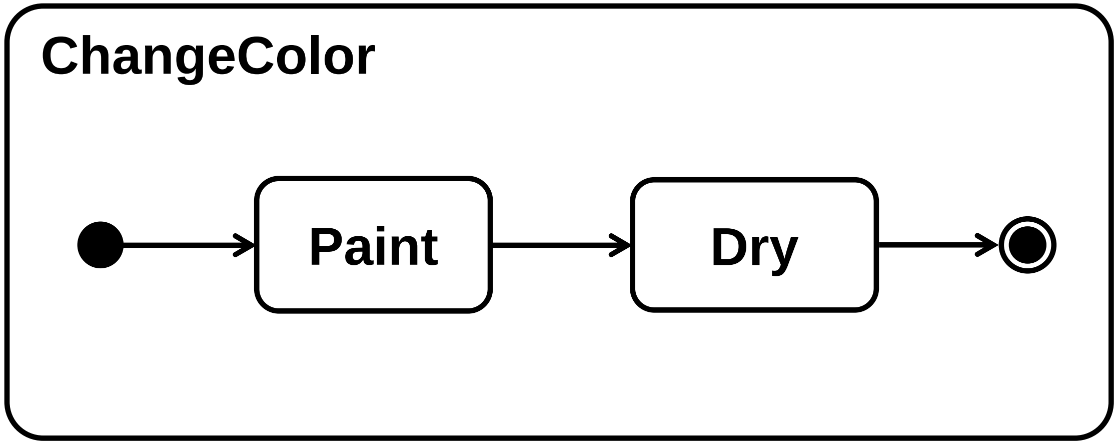
Constraint Language

- In CLIF:

```
(forall (?occPaint)
 (if
   (and (occurrence_of ?occPaint Paint)
        (legal ?occPaint))
   (exists (?occDry)
     (and (legal (successor Dry ?occDry))
          (forall (?otherSuccessor)
            (if
              (not (= ?otherSuccessor
                     (successor Dry ?occPaint)))
              (not (legal ?otherSuccessor))))))))
```

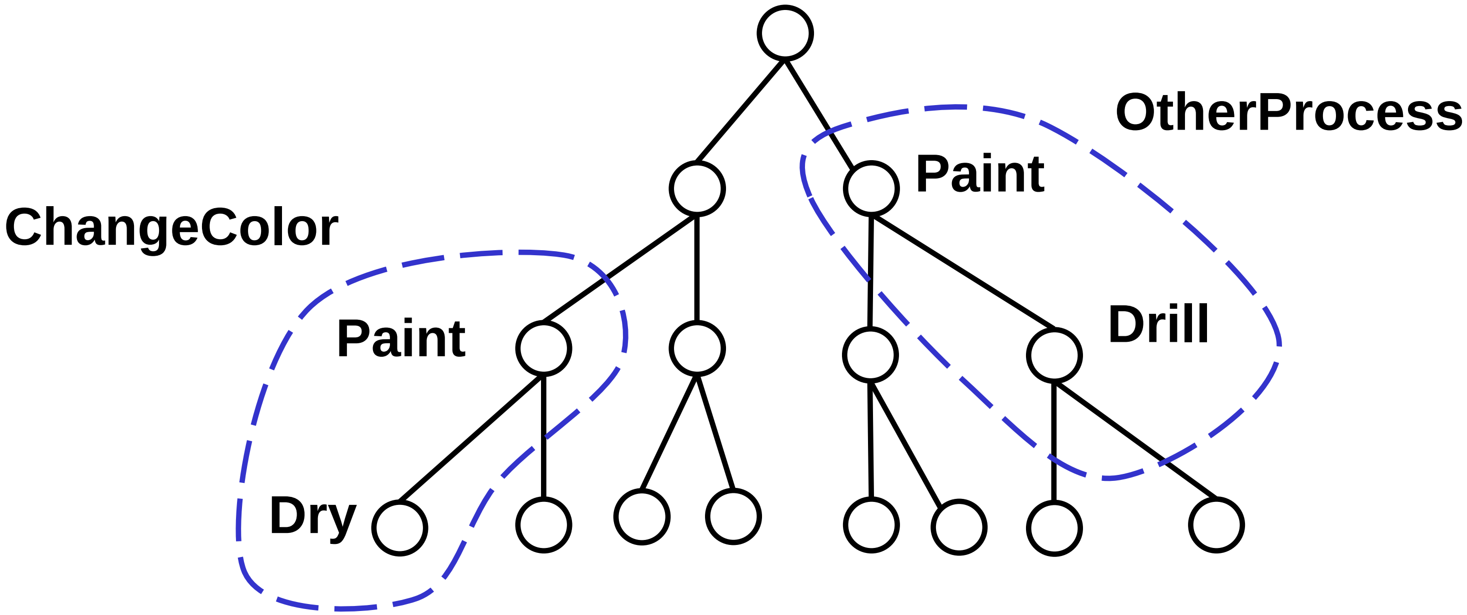
red = first order logic
occurrence_of = PSL
black = engineer’s process

Processes in PSL



- **Above says that Dry happens after Paint *under executions of ChangeColor*.**
- **Outside of ChangeColor Paint can occur without Dry.**

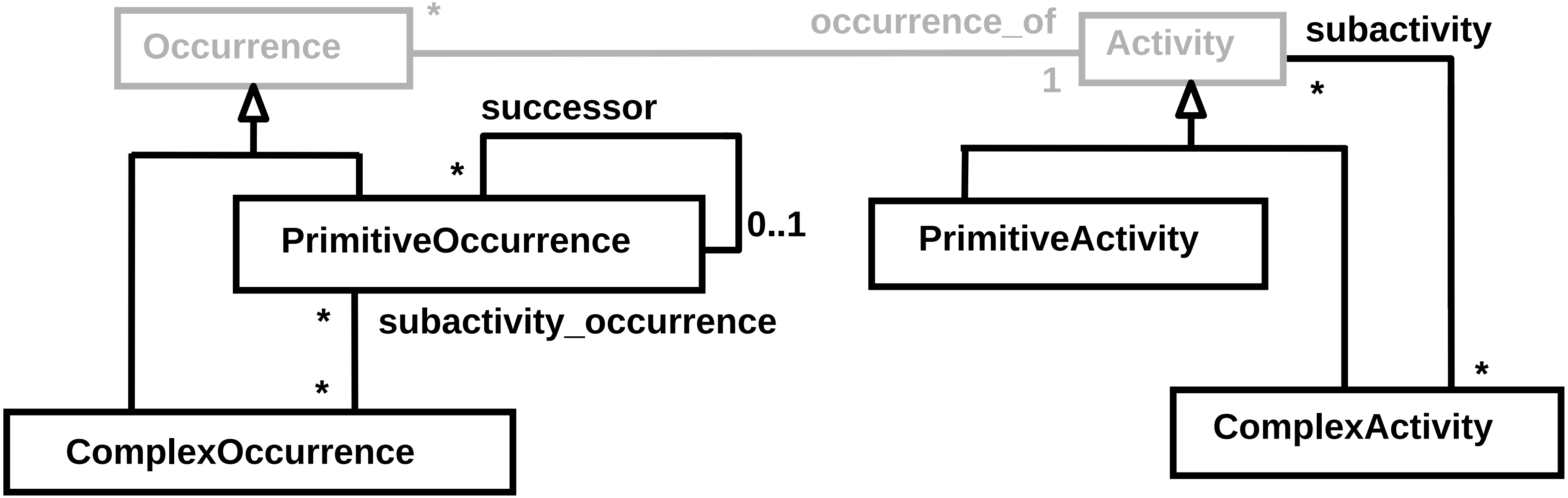
Processes as Occurrence Constraints



- Paint happens immediately after Dry under executions of ChangeColor.
- ChangeColor specification does not constrain OtherProcess above

Complex Processes in PSL

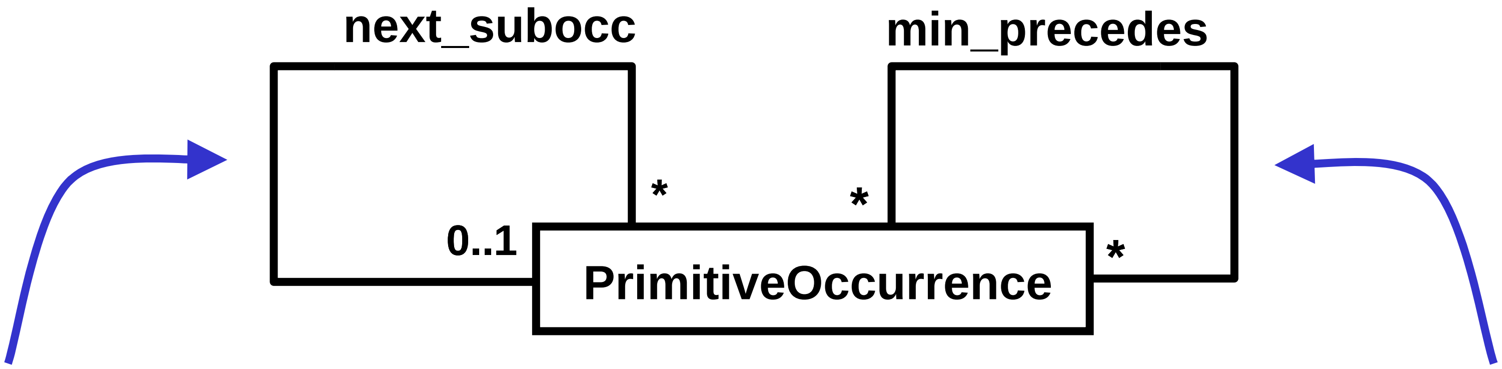
- Complex occurrences and activities composed of primitive ones:



- Successor moved to PrimitiveOccurrence.
- Occurrence tree covers every step at finest level of granularity.

Complex Processes in PSL

- **Execution sequencing within complex activity:**



Occurrences following *immediately*

Occurrences following *sometime*, not necessarily immediately.

- **(Defined in terms of successor)**

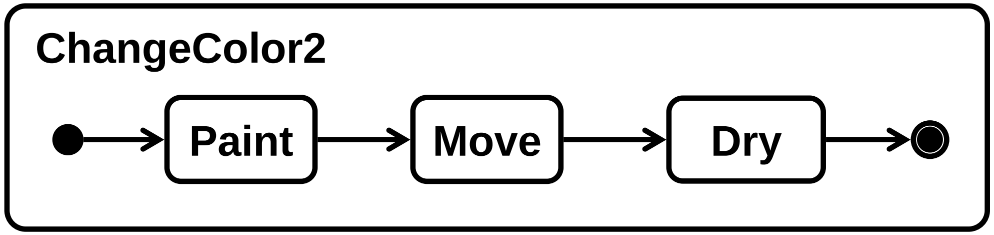
Complex Processes in PSL

- **Constrain occurrences of ChangeColor to be composed of sequential occurrences of Paint and Dry:**

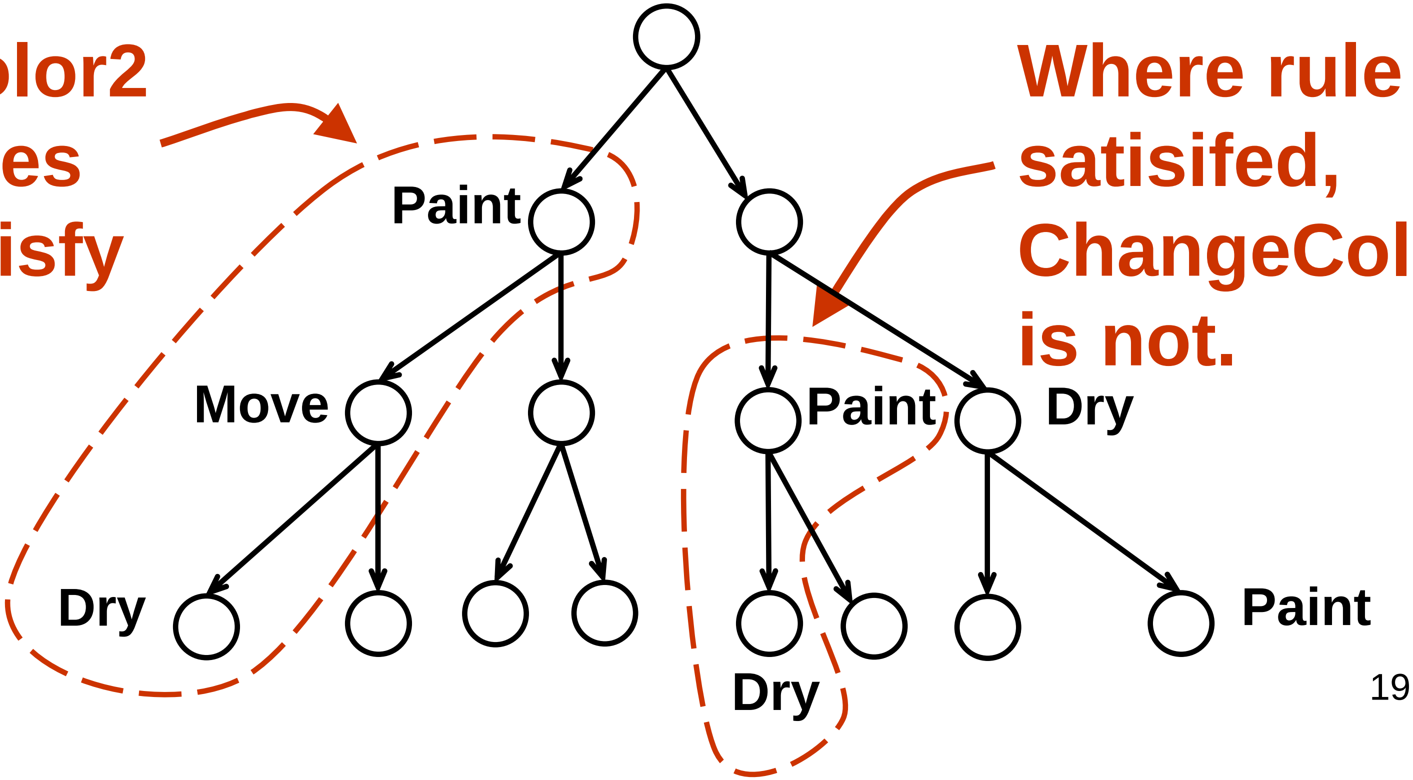
```
(forall (?occChangeColor)
  (if
    (occurrence_of ?occChangeColor ChangeColor)
    (exists (?occPaint ?occDry)
      (and (occurrence_of ?occPaint Paint)
           (occurrence_of ?occDry Dry)
           (subactivity_occurrence ?occPaint ?occChangeColor)
           (subactivity_occurrence ?occDry ?occChangeColor)
           (next_subocc ?occPaint ?occDry
                        ChangeColor)))))
```

Rule / Process Consistency

- **Rule: drying immediately follows all painting.**
- **Process:**



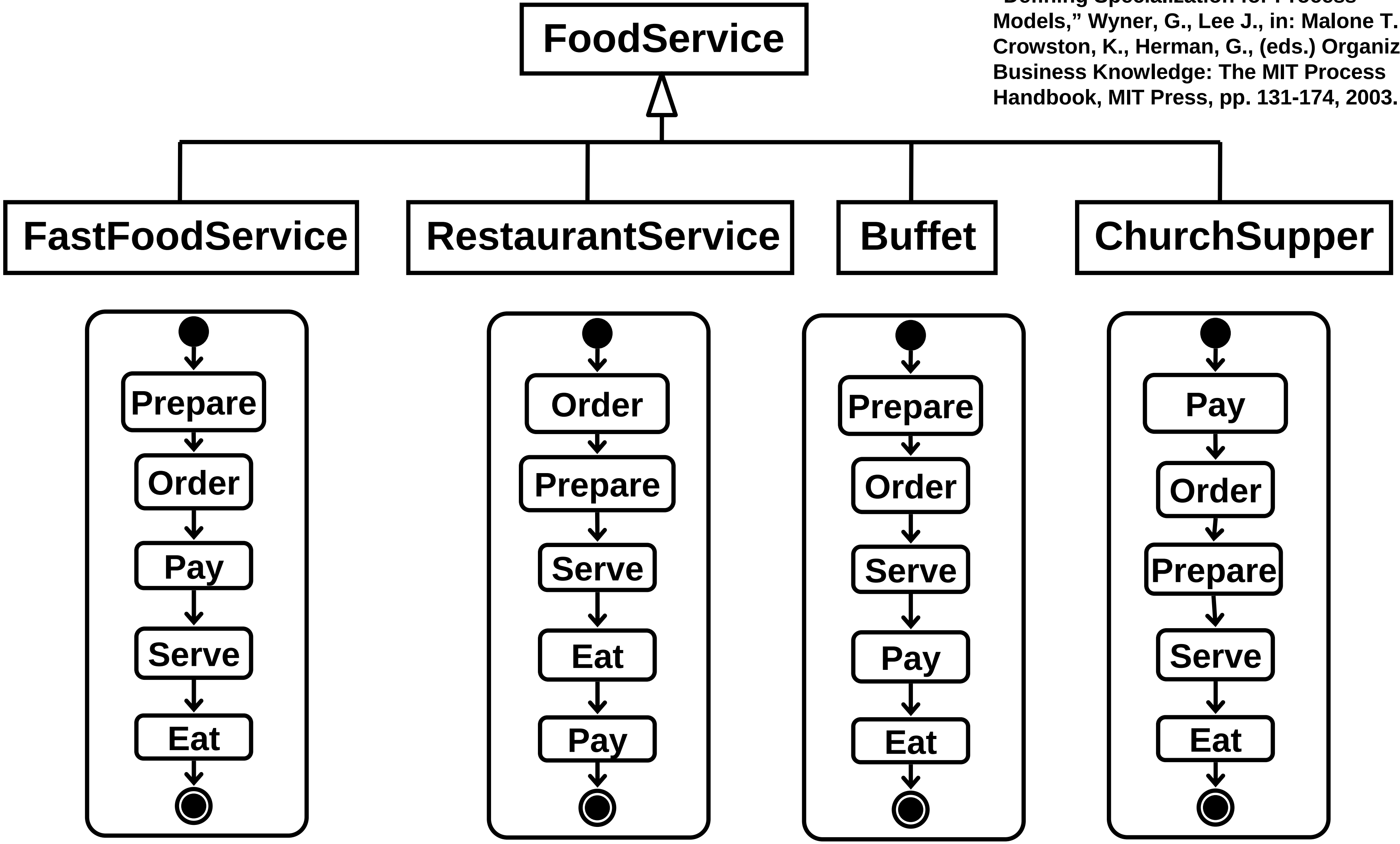
ChangeColor2 occurrences do not satisfy rule.



Where rule is satisifed, ChangeColor2 is not.

Behavior Classification

"Defining Specialization for Process Models," Wyner, G., Lee J., in: Malone T., Crowston, K., Herman, G., (eds.) Organizing Business Knowledge: The MIT Process Handbook, MIT Press, pp. 131-174, 2003.



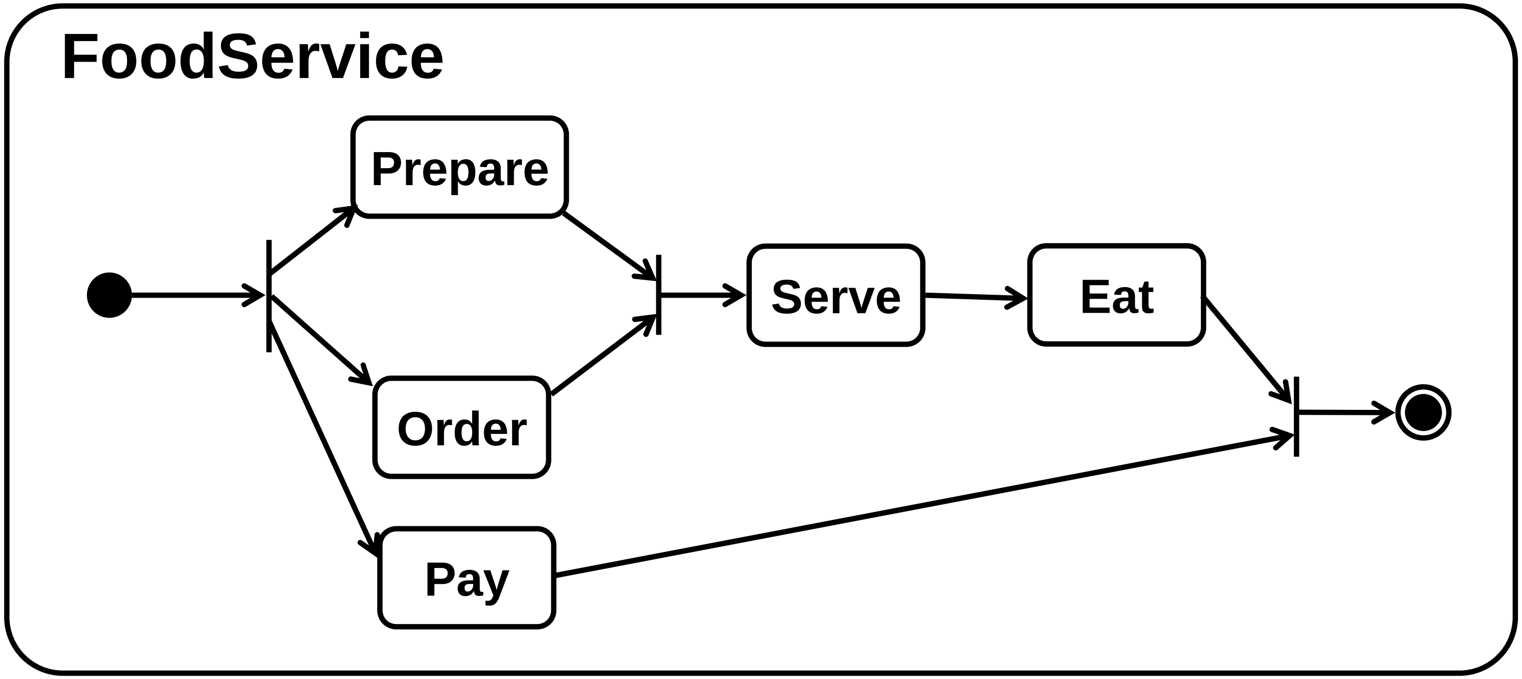
- **How to abstract commonality?**

Behavior Classification

- **Food Service has these steps:**
  - **Order, Prepare, Serve, Eat, Pay**
- **With these constraints:**
  - **Order, Prepare, and Serve always happen before Eat.**
  - **Serve happens after Prepare and Order.**
  - **Pay can happen anytime in the process.**
- **Fast Food Service adds:**
  - **Prepare before Order.**
- **Need to *partially* specify a process …**
- **… and incrementally build up constraints.**

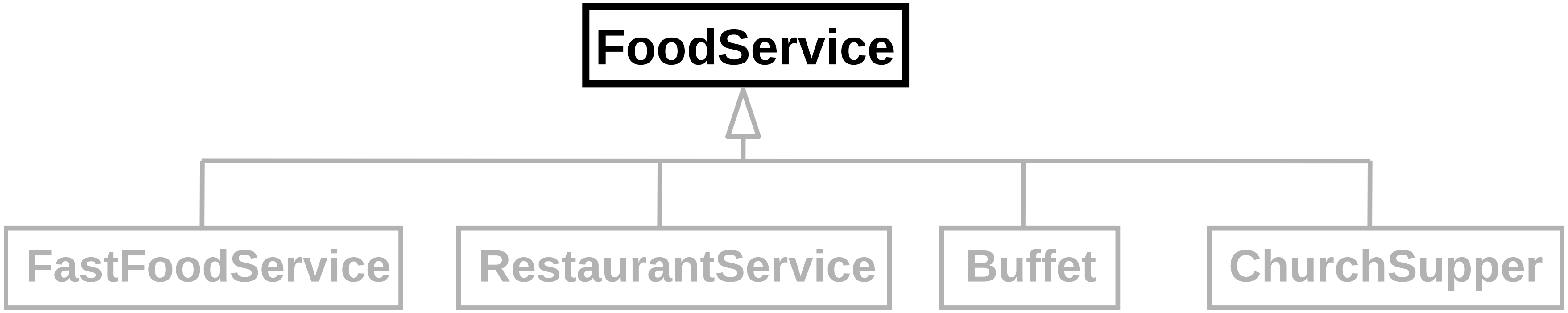
Behavior Classification

- Flow models are not expressive enough:



- Prepare and Order are not concurrent.
- Pay is not concurrent with other steps.

Behavior Classification



FoodService

FastFoodService

RestaurantService

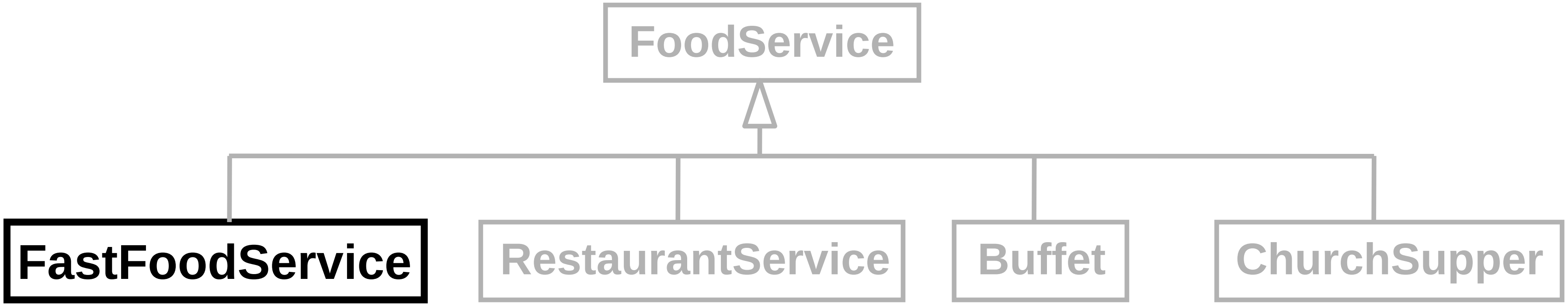
Buffet

ChurchSupper

- **FoodService: Prepare sometime before Eat.**

```
(forall (?occFoodService)
  (if
    (occurrence_of ?occFoodService FoodService)
    (exists(?occPrepare ?occEat)
      (and
        (occurrence_of ?occPrepare Prepare)
        (occurrence_of ?occEat Eat)
        (subactivity_occurrence ?occPrepare ?occFoodService)
        (subactivity_occurrence ?occServe ?occFoodService)
        (min_precedes ?occPrepare ?occEat
                          FoodService)))))
```

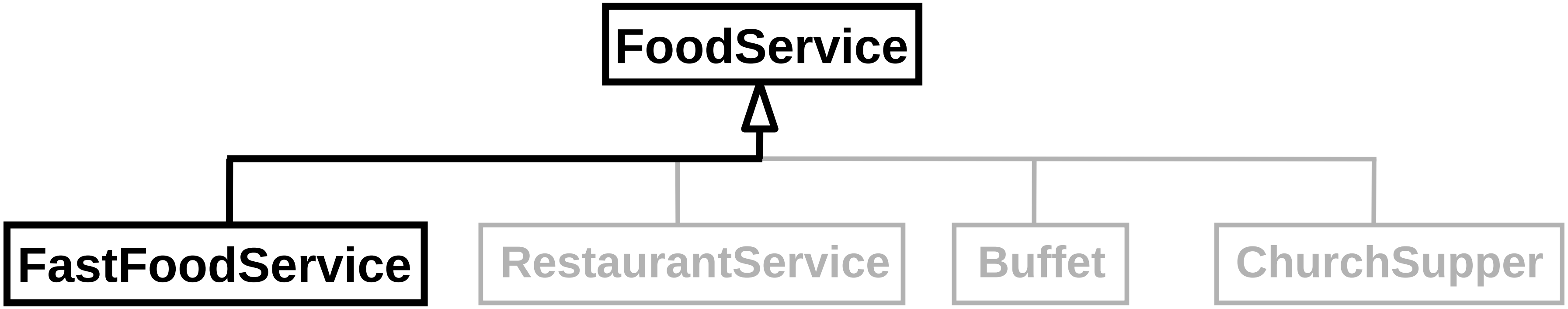
Behavior Classification



- **FastFoodService: Prepare sometime before Order.**

```
(forall (?occFastFoodService)
  (if
    (occurrence_of ?occFastFoodService FastFoodService)
    (exists (?occPrepare ?occOrder ?occFoodService)
      (and
        (occurrence_of ?occPrepare Prepare)
        (occurrence_of ?occOrder Order)
        (subactivity_occurrence ?occPrepare ?occFoodService)
        (subactivity_occurrence ?occOrder ?occFoodService)
        (min_precedes ?occPrepare ?occOrder
                      FoodService)))))
```

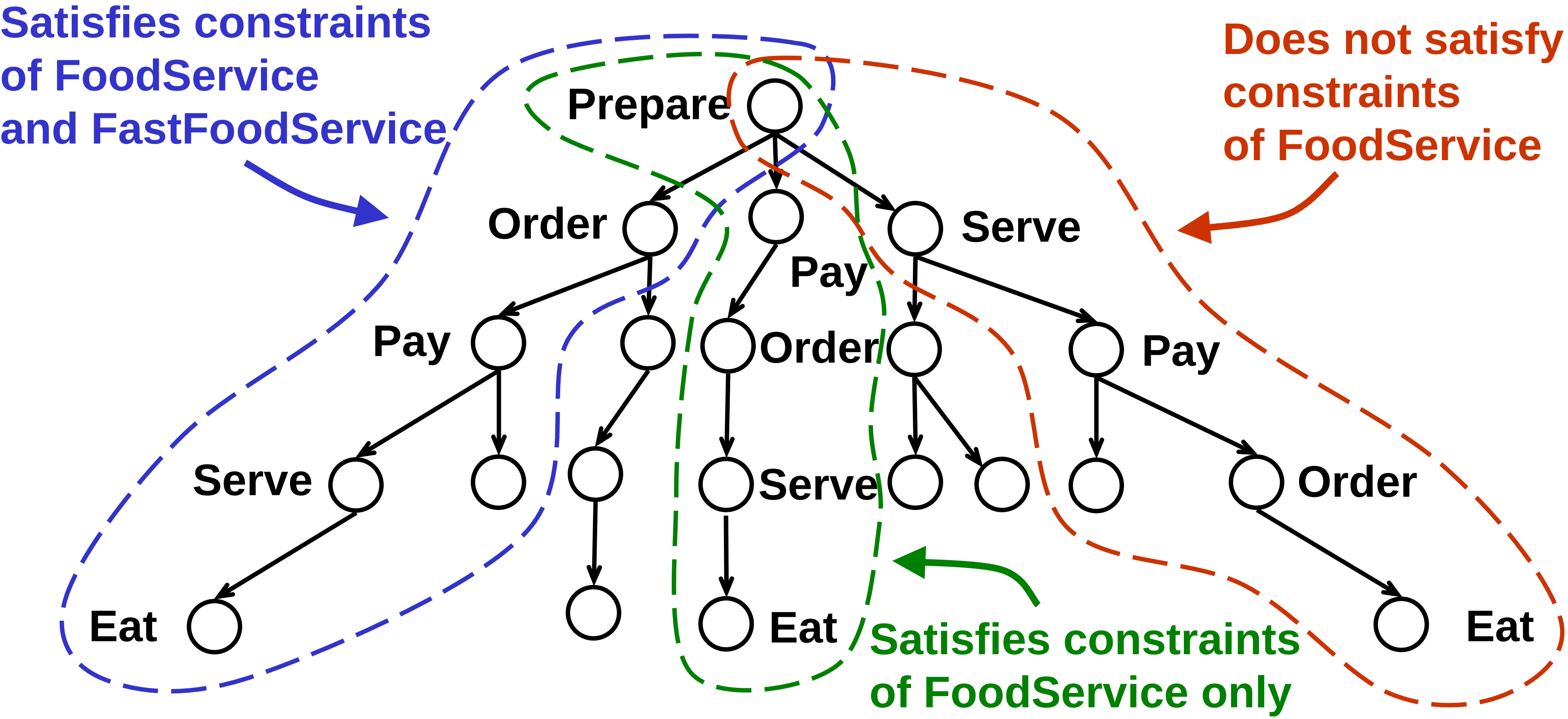
Behavior Classification



- **Classification of process executions:**
  - **All subactivity occurrences of FastFoodService occurrences are subactivity occurrences of FoodService occurrences.**

```
(forall (?occFFS)
  (if (occurrence_of ?occFFS FastFoodService)
      (exists (?occFS)
         (and (occurrence_of ?occFS FoodService)
              (forall (?s)
                 (if (subactivity_occurrence ?s ?occFFS)
                     (subactivity_occurrence ?s ?occFS)))))))
```

Behavior Classification



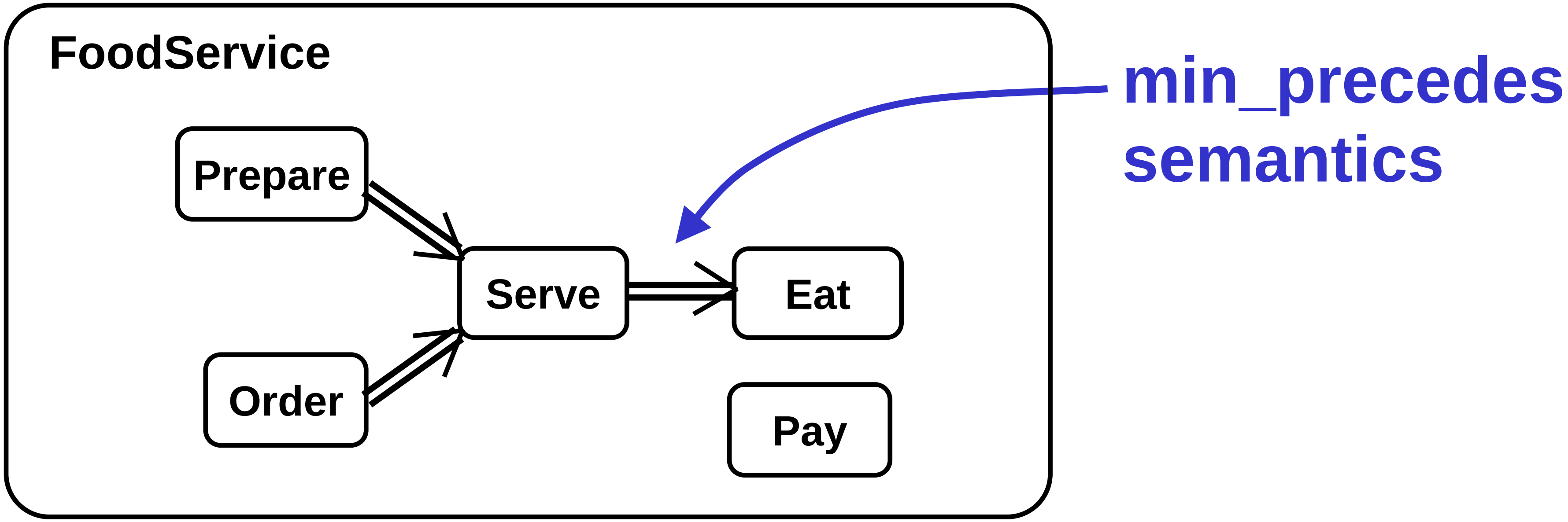
Satisfies constraints of FoodService and FastFoodService

Does not satisfy constraints of FoodService

Satisfies constraints of FoodService only

- **Execution traces conforming to general and/or specific process constraints, or not.**

Behavior Classification



- **Possible enhancement to UML notation.**
- **(Requires updating tools and services ...**
- **… compared to extending CLIF representation)**

Web Service Queries

- Buy a book:
  - without using a credit card.
  - credit card charged only when shipped.

  (adapted from example by Michael Gruninger)
- Shipping:
  - transport frozen vegetables from San Francisco to DC.
- Substituting:
  - a web service with another that achieves the desired effects at lower cost.

Web Service Queries

- Web service posts specification of the public aspects of their process.
- Query is a specification of the desired aspects of a process.
- Answer tells which web service are consistent with the query.
  - Which posted specifications are generalizations of the query?

Web Service Queries

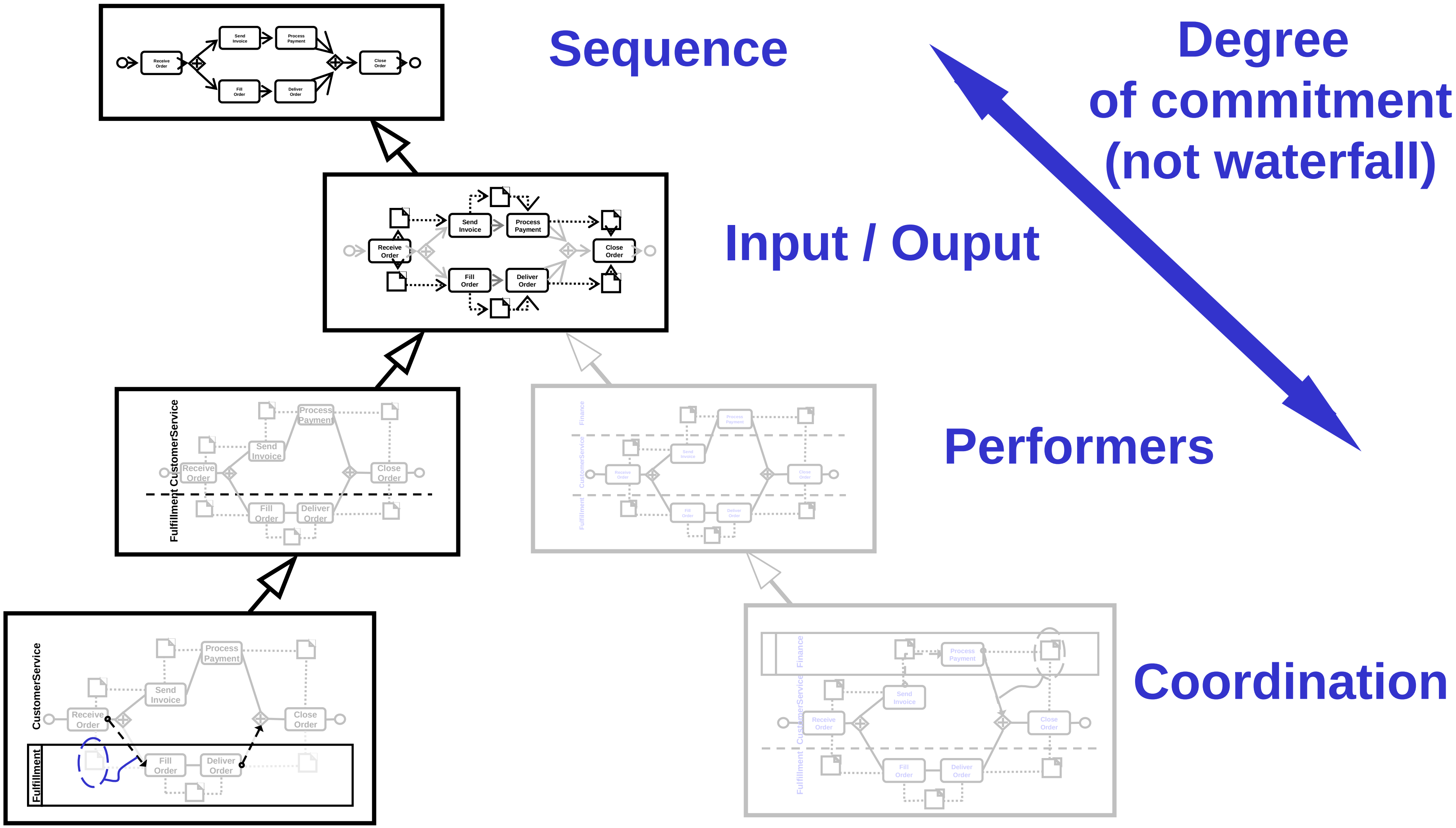
- Buy a book without using a credit card.

```
(forall (?occ)
   (if (occurrence_of ?occ DesiredProcess)
       (and (exists (?s1)
               (and (occurrence_of ?s1 ShipBook)
                    (subactivity_occurrence ?s1 ?occ)))
            (not (exists (?s2)
                    (and (occurrence_of ?s2 ChargeCreditCard)
                         (subactivity_occurrence ?s2 ?occ)))))))
```

- ... with credit card charged after ship.

```
(forall (?occ)
   (if (occurrence_of ?occ DesiredProcess)
       (exists (?s1 ?s2)
          (and (occurrence_of ?s1 ShipBook)
               (subactivity_occurrence ?s1 ?occ)
               (occurrence_of ?s2 ChargeCreditCard)
               (subactivity_occurrence ?s2 ?occ)
               (min_precedes ?s1 ?s2 DesiredProcess)))))
```

Refinement Rollback



Sequence

Input / Ouput

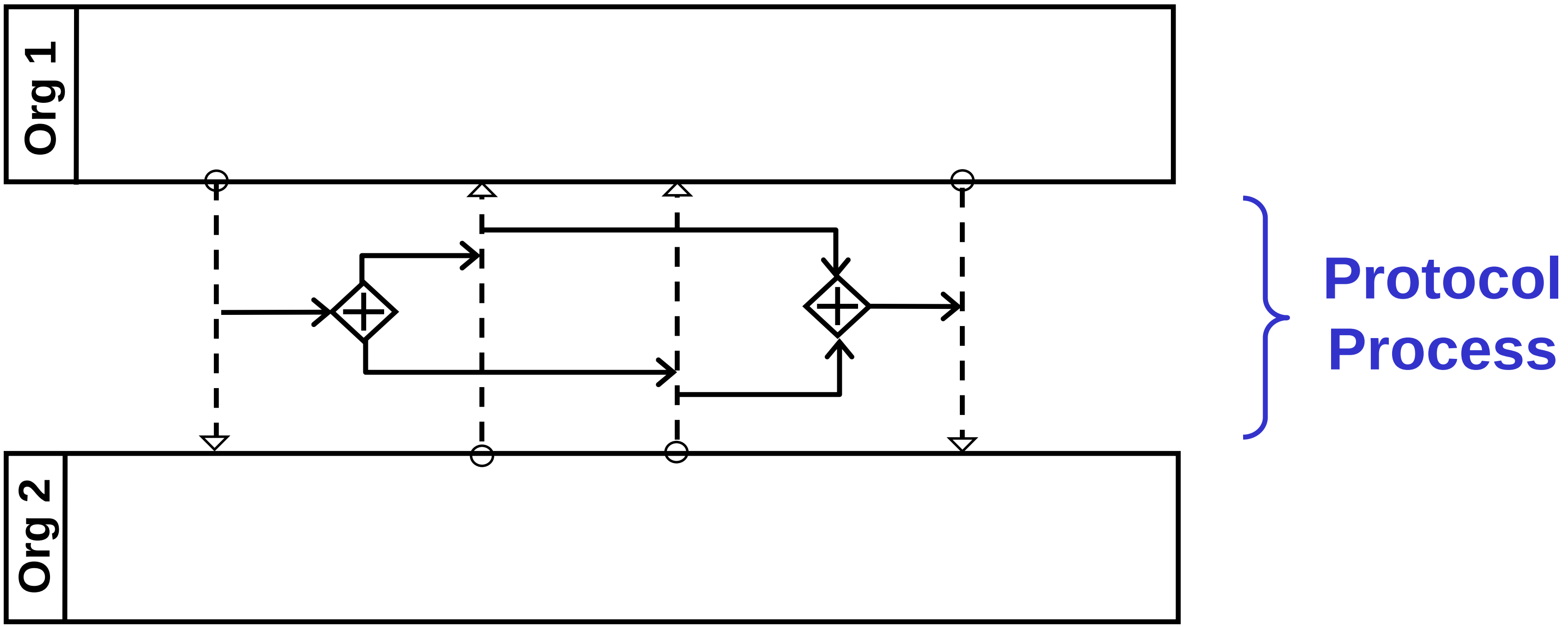
Performers

Coordination

Degree of commitment (not waterfall)

- **Alternative process commitments.**

Protocol Processes



- Constraints on messages (as subprocesses)
  - After first message arrives at Org 2, second two are sent in parallel to Org 1.
  - After those both arrive at Org 1, last message is sent to Org2.
- For defining standard or contractual interactions (eg, RosettaNet).

Process / Rule Consistency

- Business rules and processes are usually represented in incomparable languages.
- In PSL, they are both constraints on processes.
- Can automatically check consistency of rules and processes.
  - By law, a ship heading to a US port has to provide a cargo report to US Customs 24 hours before it sails.

Process / Rule Consistency

- Customer relationship management processes at IBM too complicated to verify manually.
- Represented company policies as constraints on business processes.
- Tested consistency with PSL translation of those processes.
- Identified ten problems, four of which had not been discovered by rollout.

- Gruninger, M., Atefi, K., and Fox, M.S., “Ontologies to support process integration in enterprise engineering,” Computational and Mathematical Organization Theory, 6:381-394, 2000.
- Atefi, K., "Formal models of business process reengineering for design and design validation," Ph.D. Thesis, Enterprise Integration Laboratory, Department of Mechanical & Industrial Engineering, University of Toronto, Report TR-EIL-97-1, 1997.

Partial Process Specification

- **PSL supports declaring as much or as little as needed about a process.**
  - **First order constraints on execution model.**
- **Turns ambiguity (unintentional omission) into abstraction (intentional omission).**
  - **Did the modeler intend that no other step occur between Paint and Dry?**
- **Many applications to process: categorization, search and matching, design management, protocols, rule / policy / process integrity.**

More Information

- **PSL Specification:**
  - ISO 18269, http://tinyurl.com/5j9va7, 2006.
- **Introduction:**
  - "PSL: A Semantic Domain for Flow Models," Bock, C., Gruninger, M., Journal of Software and Systems Modeling, 4:2, pp. 209-231, http://tinyurl.com/8g57x, May 2005.
- **NIST PSL site:**
  - http://www.nist.gov/psl
- **Other material:**
  - http://www.conradbock.org/#PSL
  - conrad.bock at nist.gov