Manufacturing
Engineering

UML 2 for Systems Engineering

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Unified Modeling Language

- Originated in object-oriented software community.
- However:
  - Wide lifecycle, including logical specifications and deployment.
  - More than pictures:
    - Includes a repository model/API and
    - … and XML interchange.
  - Behavior models with virtual machines.
  - Not just for software modeling.

Wide Lifecycle

- Logical and physical modeling
  - Logical entities
  - Physical and software entities
    - Environment
    - System
- Requirements
  - Use cases
  - Constraints
- Deployment
  - Artifacts
  - … tied to specification and delivery.

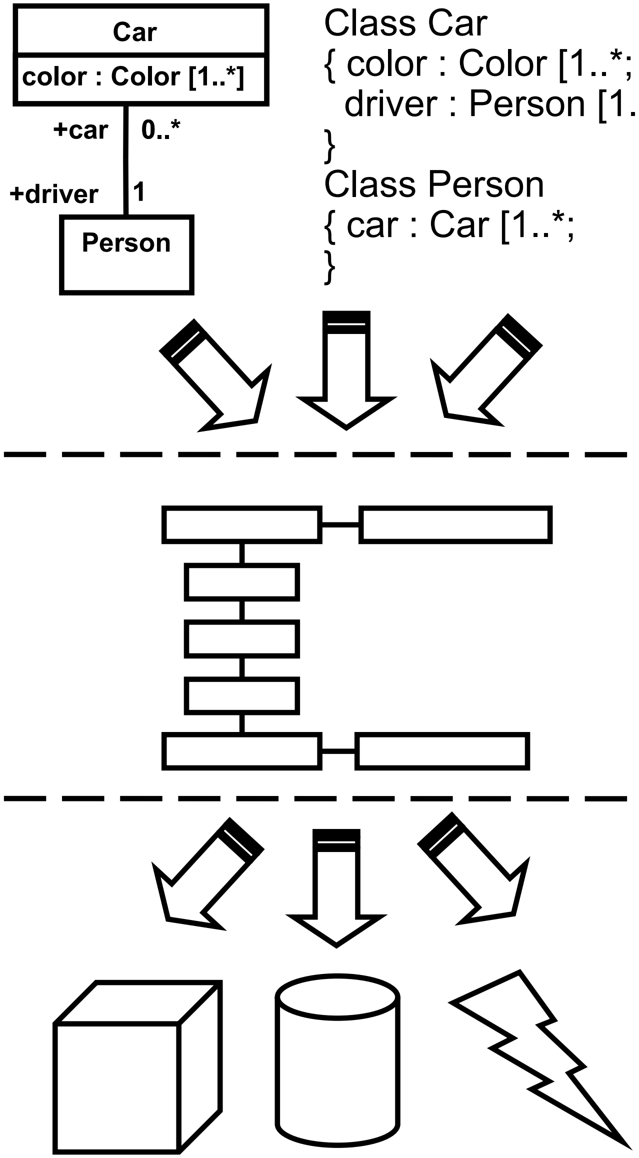
More Than Pictures

- Repository provides
  - API's
  - XML interchange
  - Support for multiple notations

- UML notation stores to repository
  … and alternate notations can, too.

- Generate systems from repository:
  Notation → Repository → System

Model-Centered Development



```
Class Car
{ color : Color [1..*;
  driver : Person [1..1]
}
Class Person
{ car : Car [1..*;
}
```

Presentation

Parsing

Repository

Model compilation

Actual system

Behavior Models

- Multiple types of model.
- None dominant.
- Different emphasis in each one:
  - Activity models
    - Series of actions
  - Interaction models
    - Messages between objects
  - State machines
    - Objects reacting to events
- Virtual machines defined for execution.

UML Status

- First version adopted in 1997 (1.1).
- Minor revision in 1999 (1.3).
- Coding models added in 2001 (1.5).
- Major revision finishing now (2.0).
- Primary submission is created by many modeling vendors and users.
- Expect adoption in mid-year, 2003.

New Areas in UML 2 for SE

- Activity model supports physical as well as computational processes.
- Composition model supports inter-part connections.
- Deployment model ties specification to delivered system.
- Information Flow.
- Time model.
- And others.

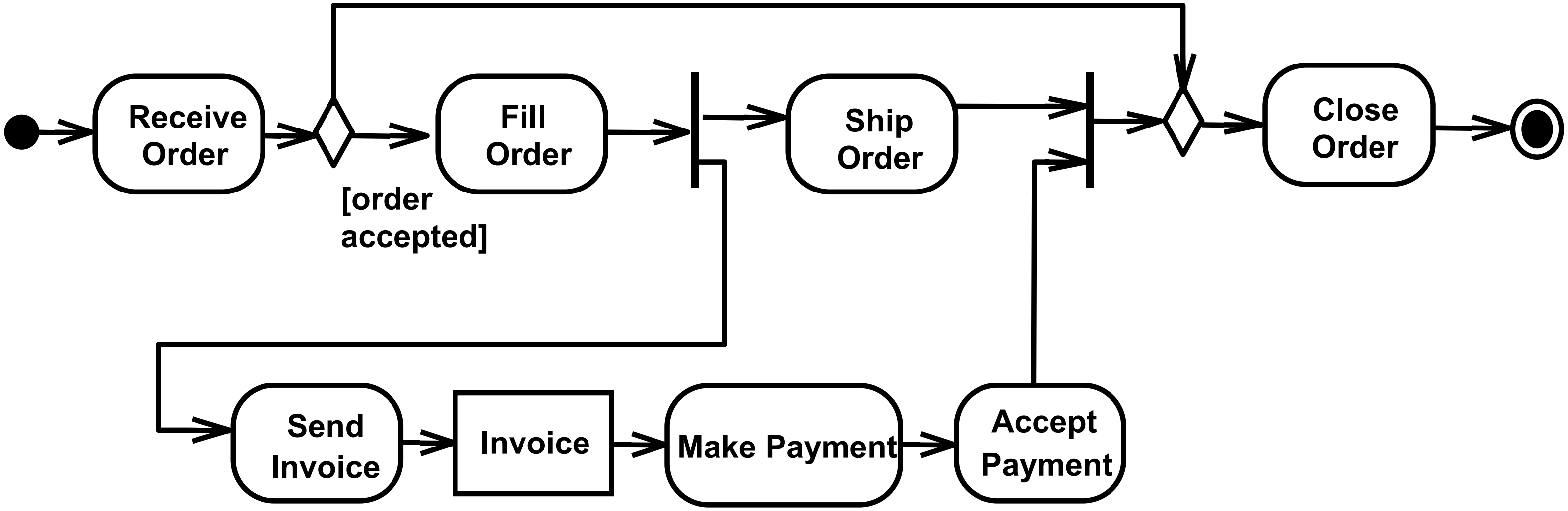
Activity Modeling

- Activity modeling emphasizes the sequence and conditions for coordinating other behaviors
- … using secondary constructs to show which classifiers are responsible for those behaviors.

- Focus is on what tasks need to be done, in what order, rather than who/what performs each task.

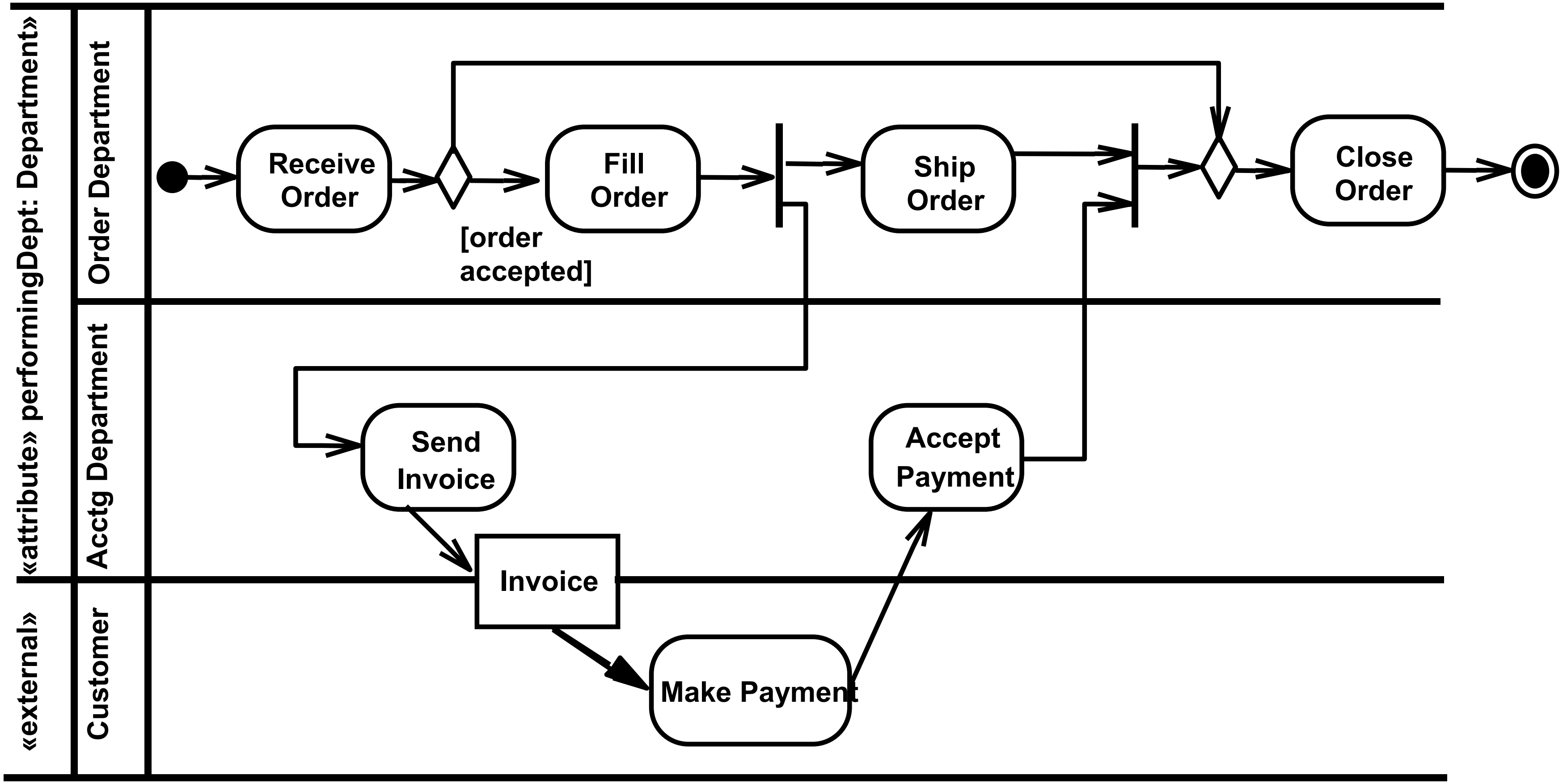
Activity Modeling

- **Tasks and ordering …**



Activity Modeling

- … plus resource assignments.



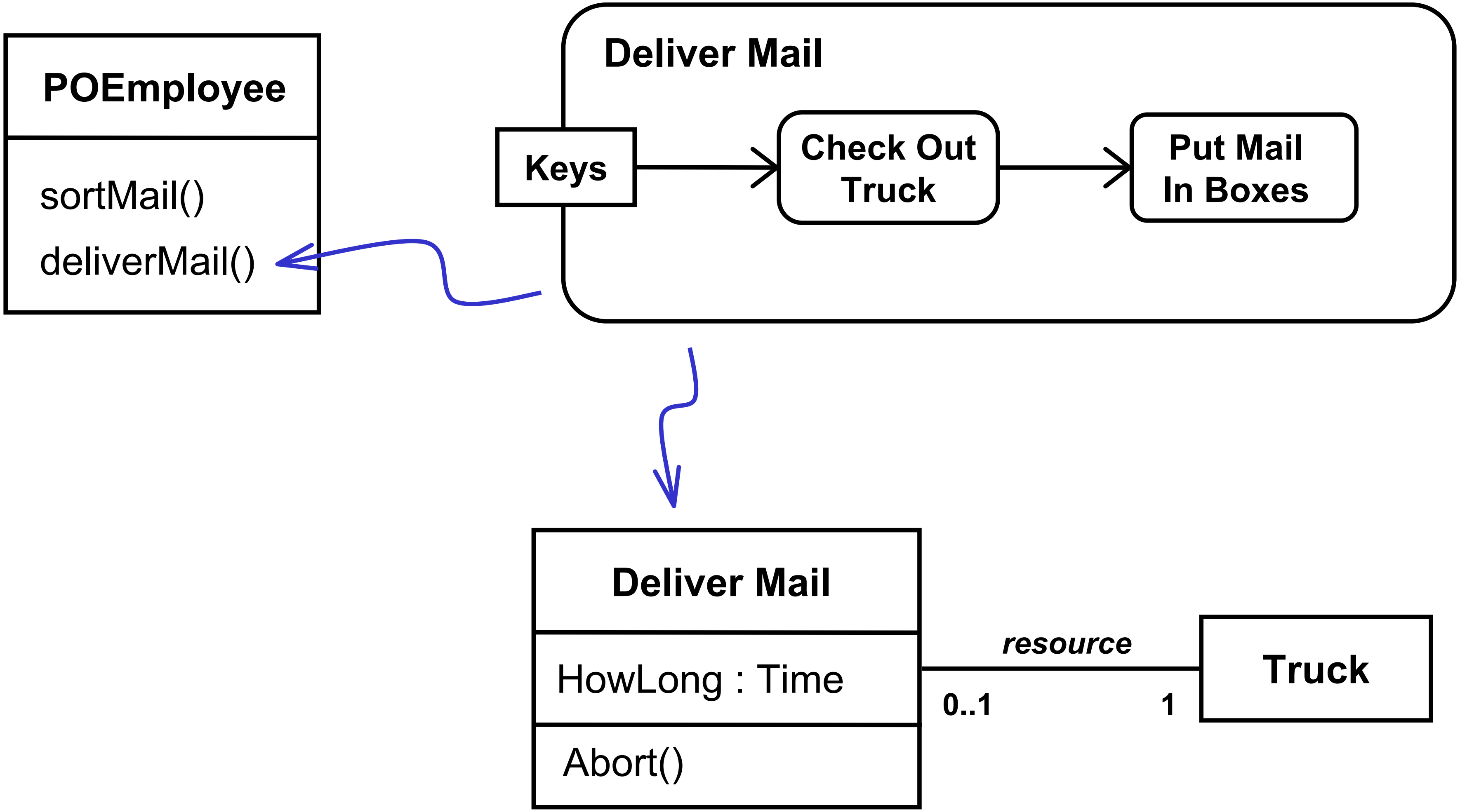
UML 2 Activities for SE

- First-class behavior model:
  - Usable with or without objects
  - Parameterized
  - Behavior properties
- Full parallelism
  - Concurrent branches operate independently.
- Input/output
  - Queuing, storage
  - Notation
  - Multi-entry/exit
- Full action model
  - For model execution and simulation.

First-class Behavior Model

- Object-orientation not required to model dynamics …
- … but supported when needed.
- Behaviors can be invoked directly, or through an object owning the behavior.
- Parameterized for input/output.
- Can have attributes, associations, operations, states, …

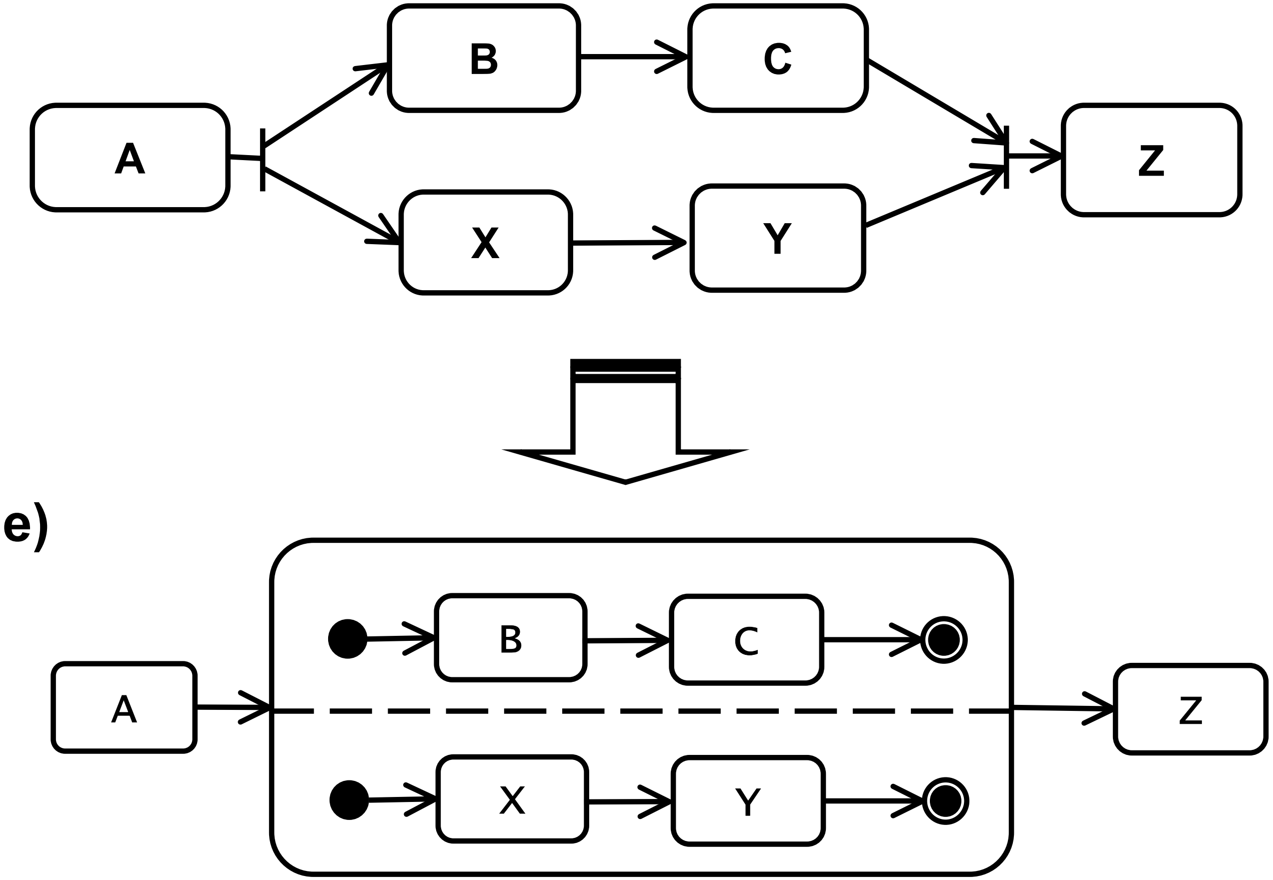
First-class Behavior Model



State-based UML 1.x Activities

(Activity)

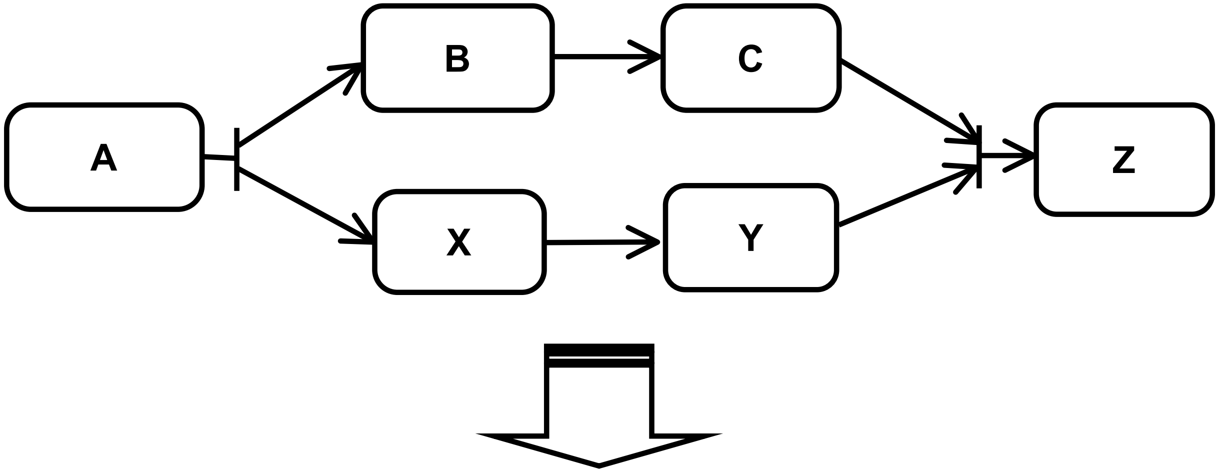
(State Machine)



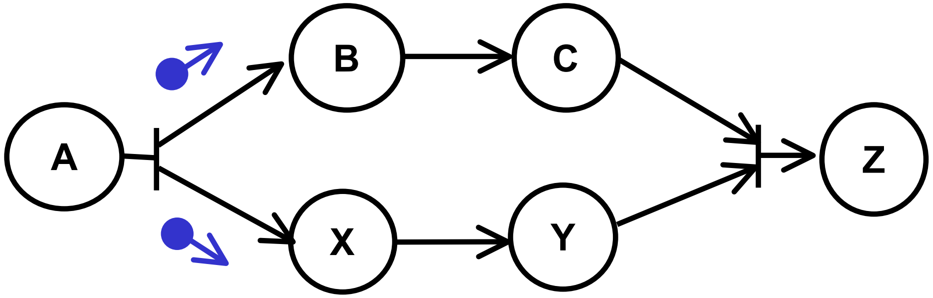
Trace: **A, B||X, C||Y, Z**

Token-based UML 2 Activities

(Activity)



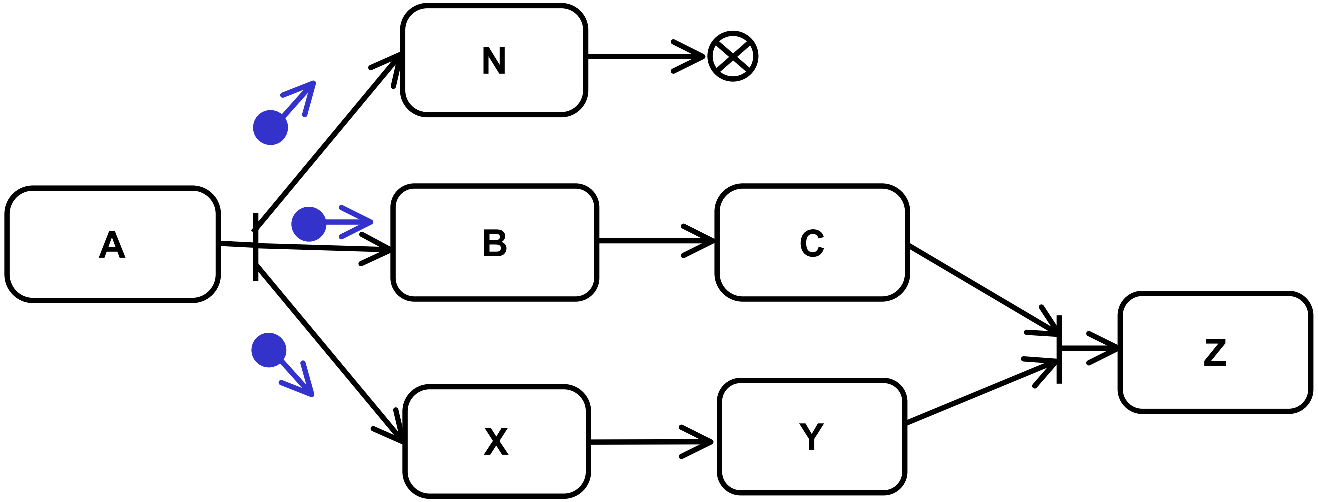
(Token flow,
***not a notation*)**



Trace: A, (B,C) , Z
|| (X,Y)

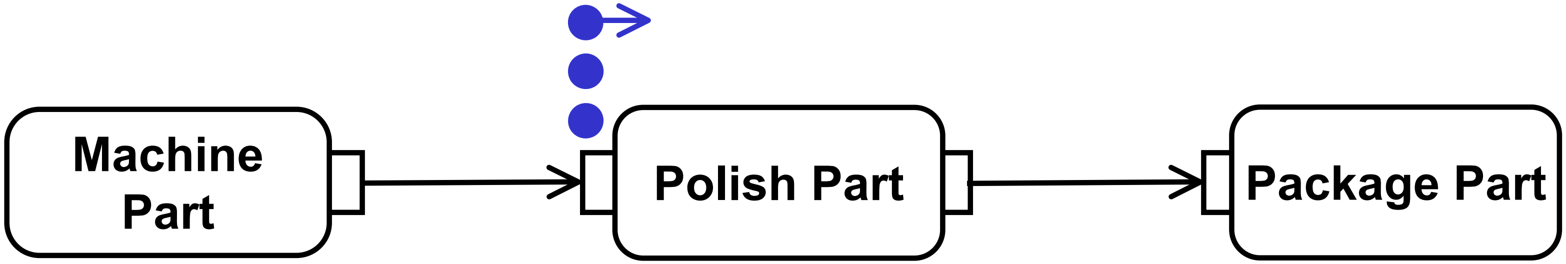
Unrestricted Parallelism in UML 2

(Activity, ***tokens not notation*****)**



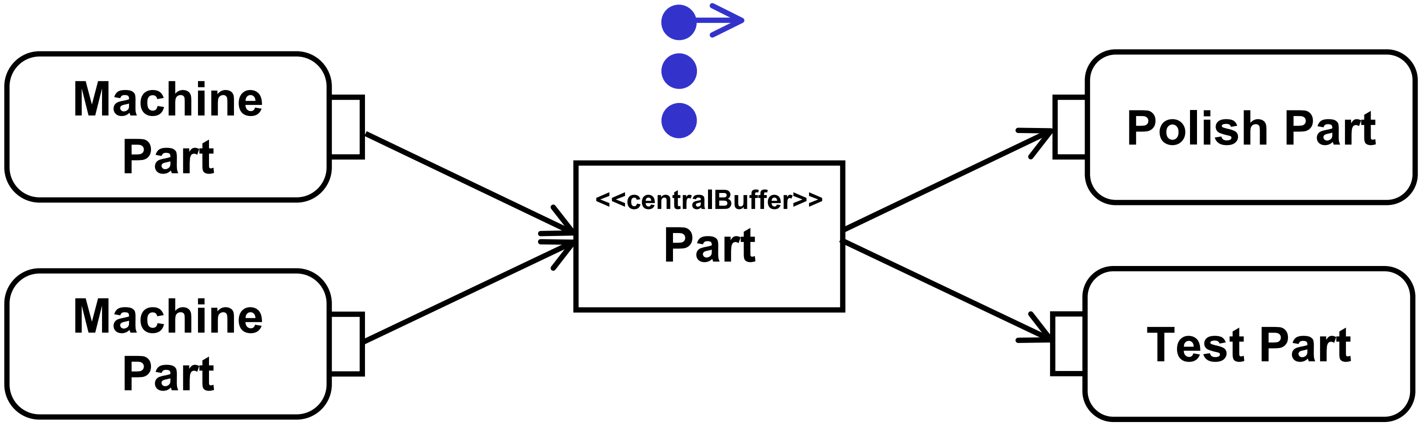
$$\textbf{Trace:}\quad A,\quad \underbrace{(B,C)\ \|\ (X,Y)}_{\|\ N}\ , Z$$

Queuing



- Tokens can
  - stack up in “in/out” boxes
  - backup in network
  - prevent upstream behaviors from taking new inputs
- Applicable to systems with significant resource constraints, such as physical or manual processes.

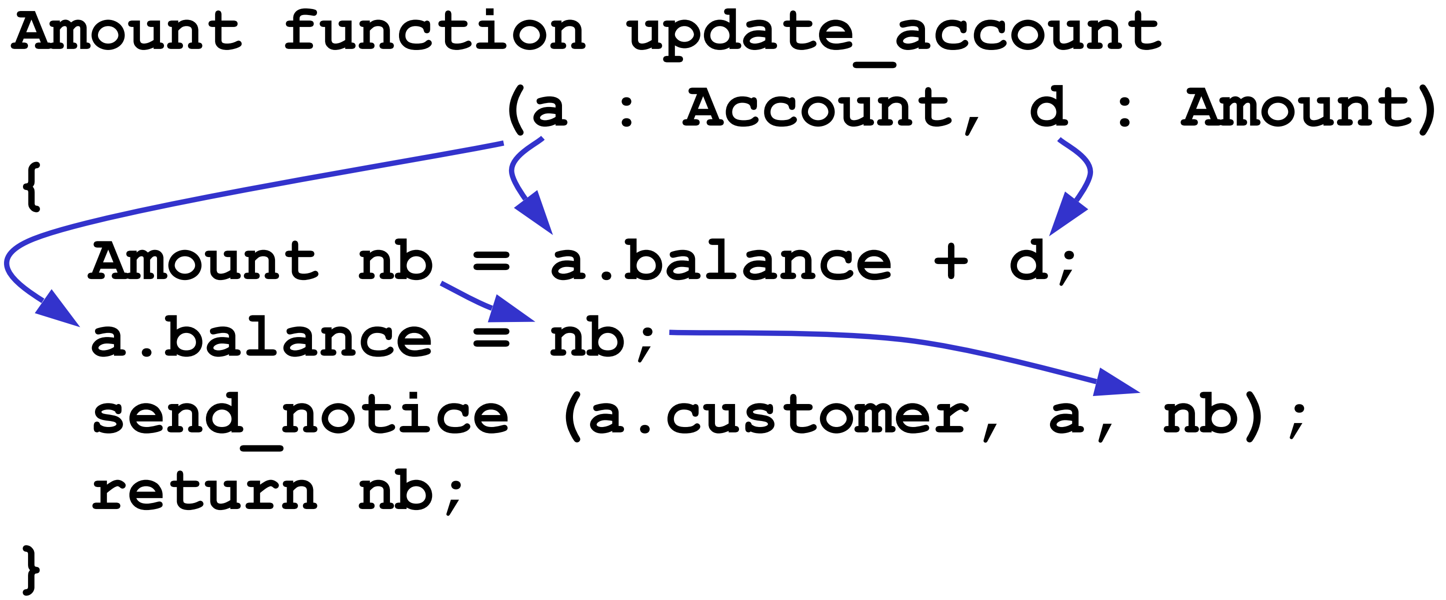
Queuing



- Tokens can be
  - Stored temporarily
  - Divided between flows
- Tokens cannot
  - Flow in more than one direction, unless copied.

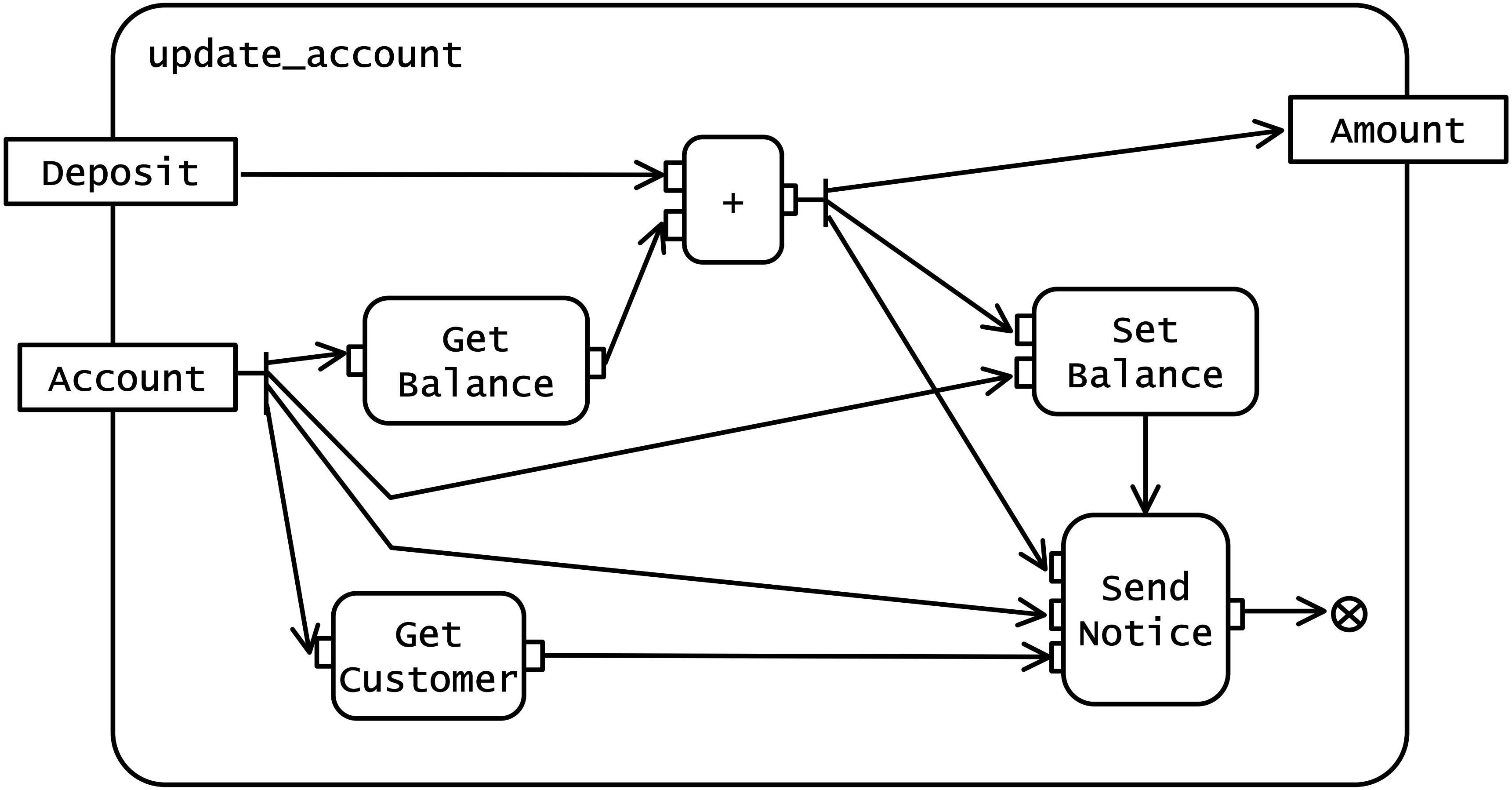
Non-queuing

- No token interaction.
- For domains without resource constraint, such as computation.

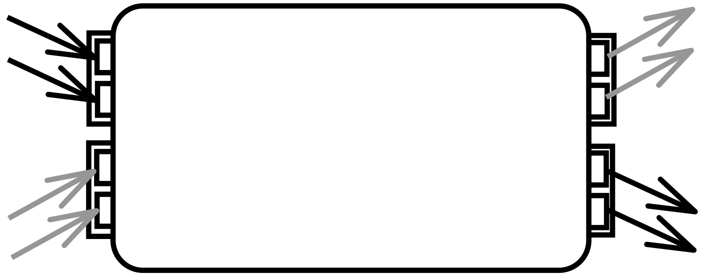


```
Amount function update_account
             (a : Account, d : Amount)
{
  Amount nb = a.balance + d;
  a.balance = nb;
  send_notice (a.customer, a, nb);
  return nb;
}
```

Non-queuing


update_account
Deposit
Account
Amount
Get Balance
+
Set Balance
Get Customer
Send Notice

Parameter Sets



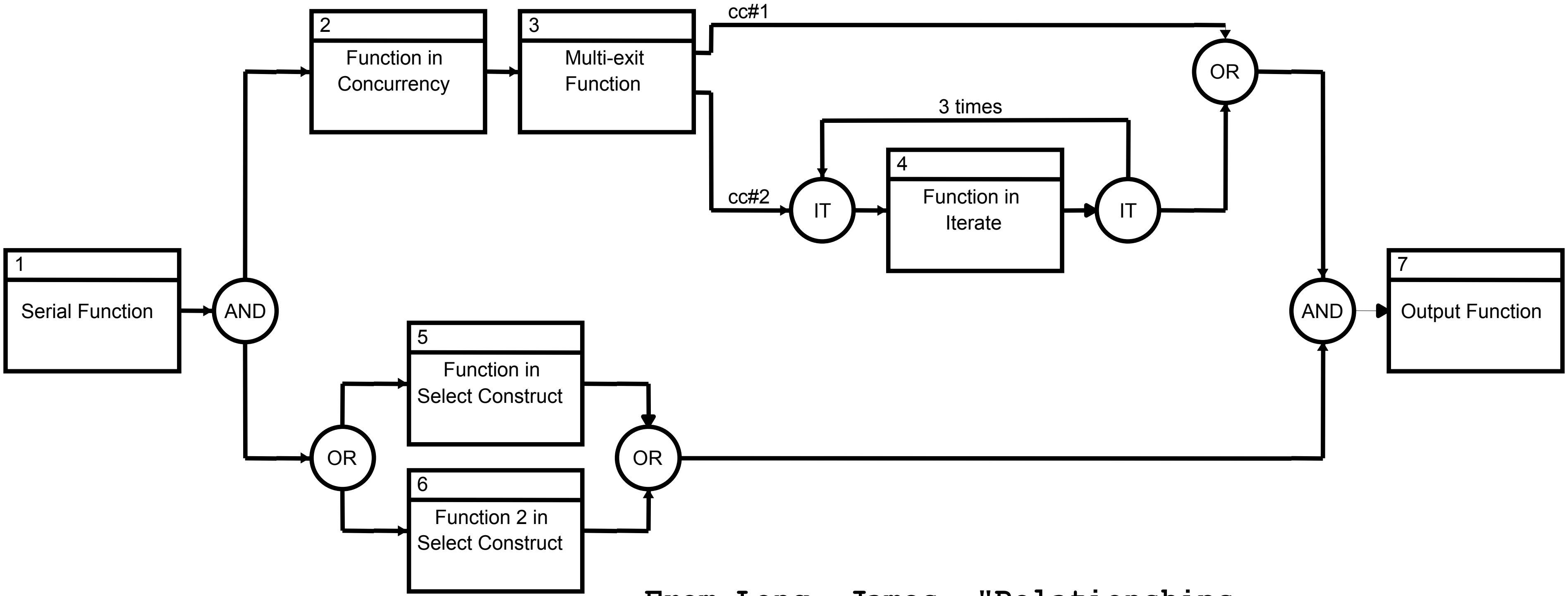
- Sets of parameters can take input or provide output ...
- … exclusive of each other at runtime.
- See multi-exit in EFFBD.

Full Action Model

- Actions are the “steps” in an activity (round-cornered rectangles).
- Include:
  - Invoking behaviors/functions.
  - Creating/destroying objects.
  - Getting/setting property values.
- For fully-executable models and simulations.

Extended Functional Flow Block Diagram

- **Control/data flow diagram.**



From Long, James, "Relationships between Common Graphical Representations in System Engineering", ViTech Corporation, www.vitechcorp.com

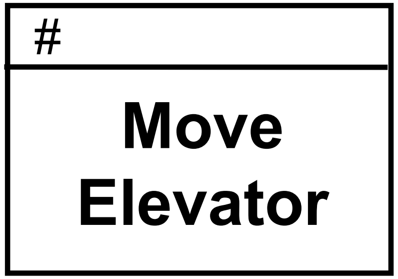
Extended Functional Flow Block Diagram

- Most of EFFBD supported by UML 2 Activity diagrams.
- Some differences in execution …
- … to be addressed in SE profile for UML 2 or in minor revision to UML.

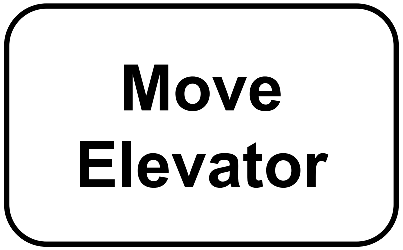
Function ←→ Behavior/Action

- **EFFBD Function and UML 2 Action/Behaviors are steps in a process flow.**

(EFFBD)



(UML 2)

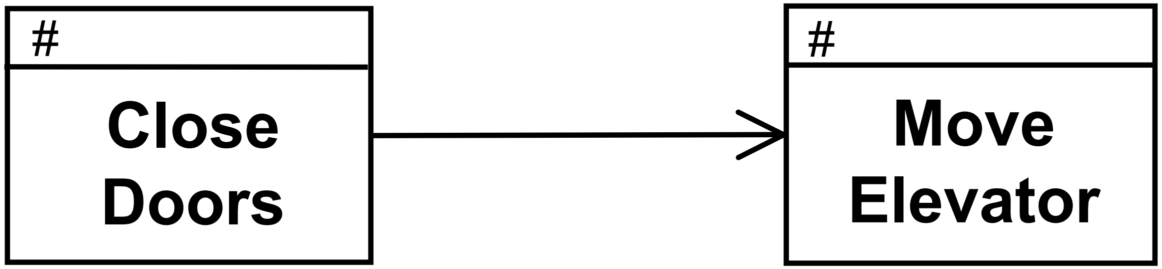


- **Notation is different, but repository would be the same** (except for adding #).

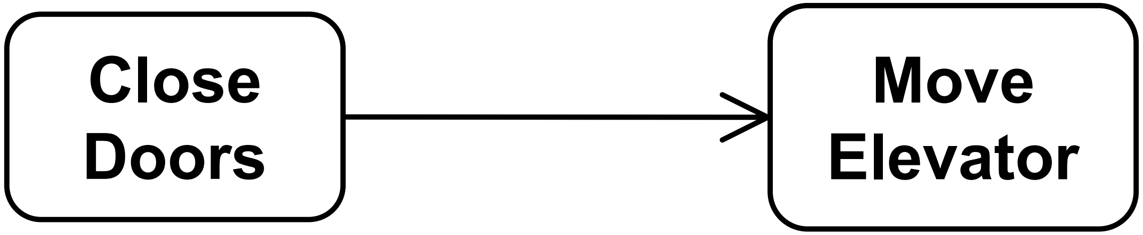
Control Flow

- **EFFBD and UML 2 Control Flow give time sequence to steps in a process flow.**

(EFFBD)



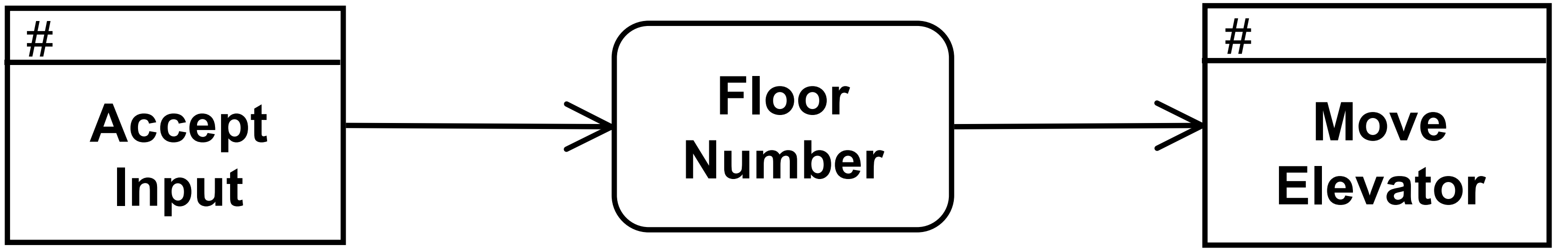
(UML 2)

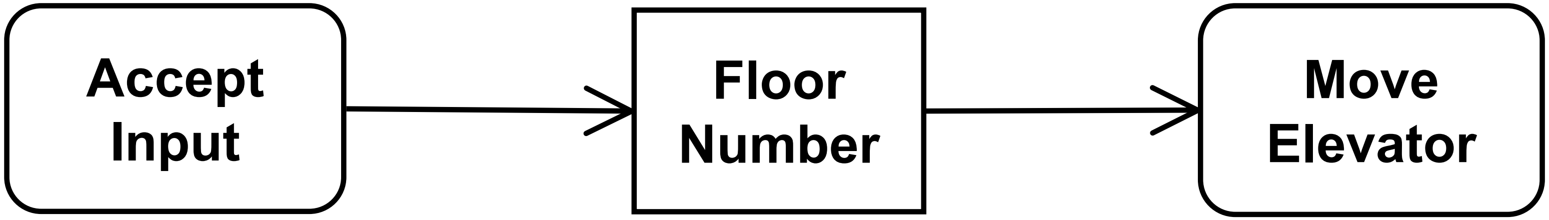


Data/Object Flow

- **EFFBD and UML 2 Data Flow specify how Function/Behavior outputs are provided to inputs.**

(EFFBD)



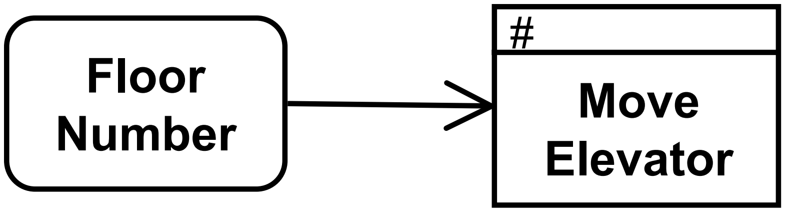


(UML 2)

External I/O ←→ Parameter

- **EFFBD External Input/Output and UML 2 Parameter support I/O at the beginning/end of the entire diagram.**

(EFFBD)

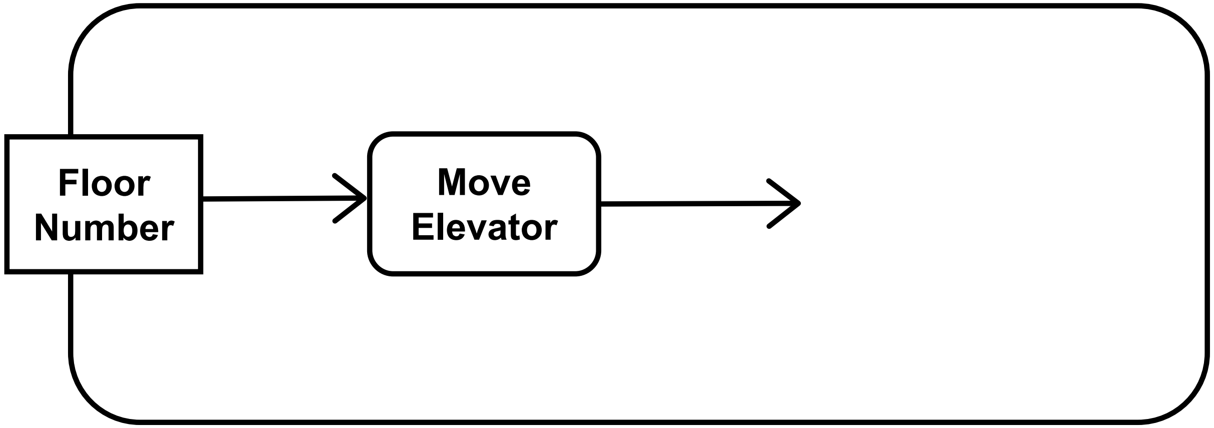


Floor Number

#

Move Elevator

(UML 2)



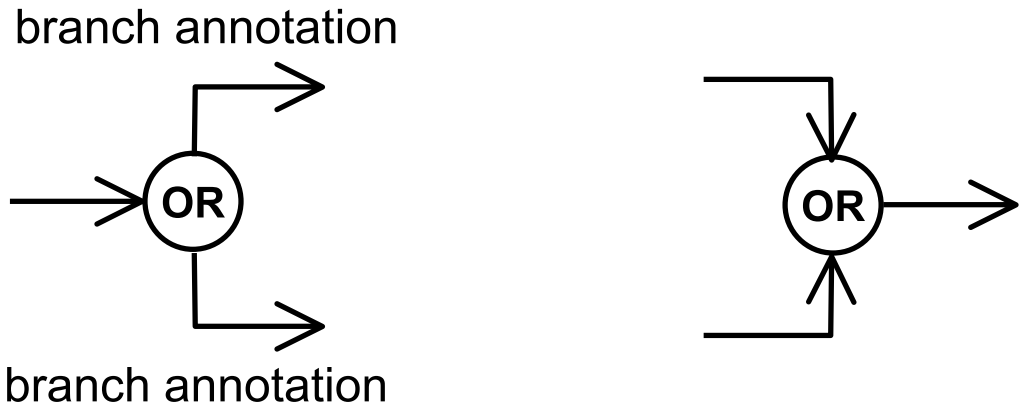
Floor Number

Move Elevator

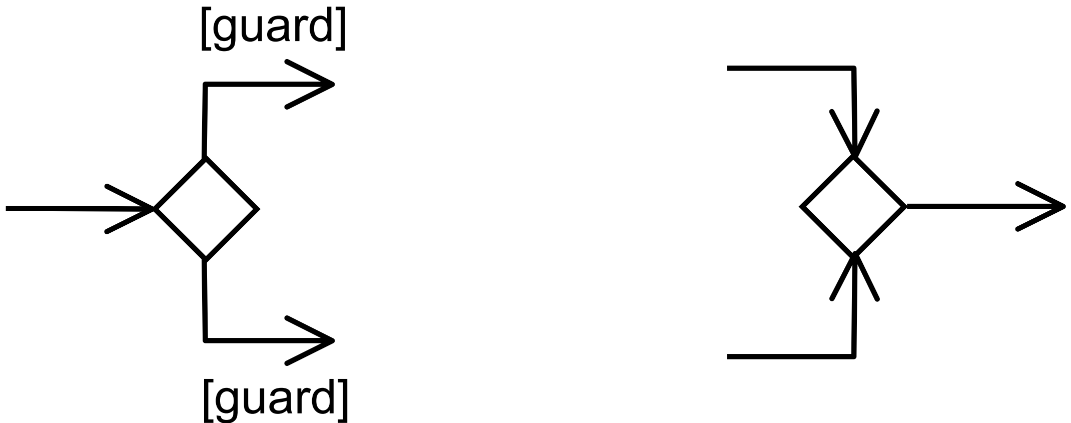
Select ←→ Decision

- **EFFBD Select and UML 2 Decision specify mutually exclusive paths in a flow.**

(EFFBD)



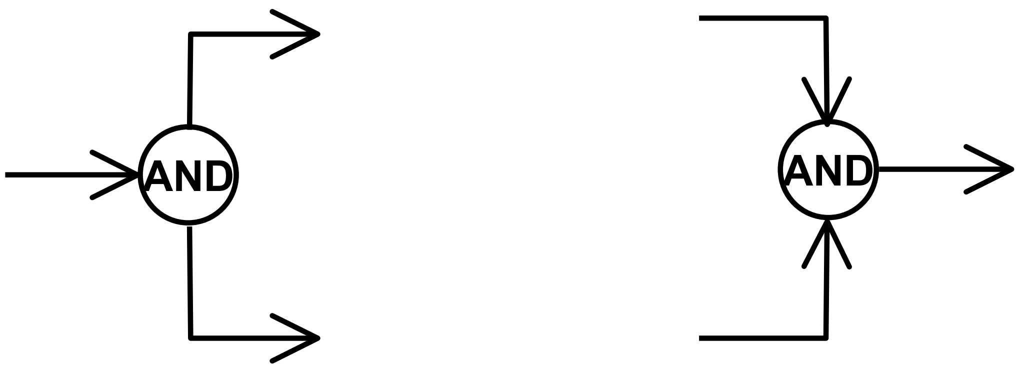
(UML 2)



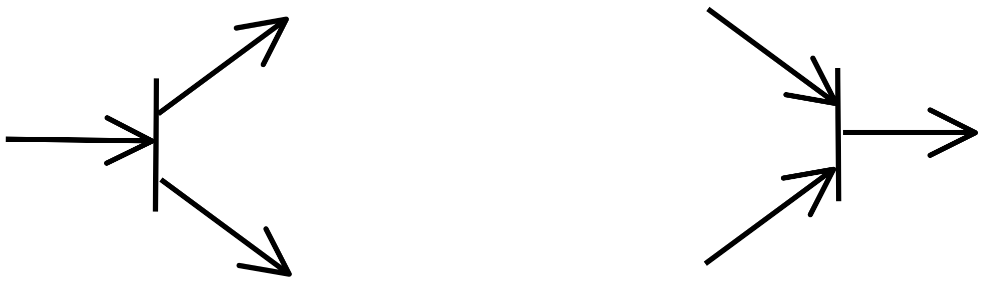
Concurrency ←→ Fork/Join

- **EFFBD Concurrency and UML 2 Fork/Join specify parallel paths**

(EFFBD)



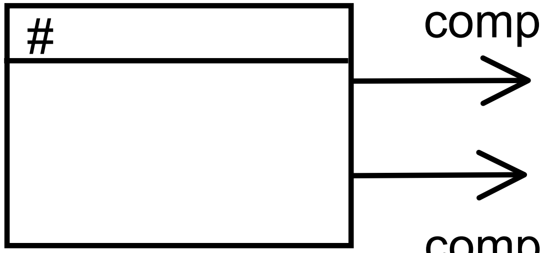
(UML 2)



Multi-exit ←→ Parameter Sets

- **EFFBD multi-exit functions and UML 2 Parameter Sets specify mutually exclusive outputs.**

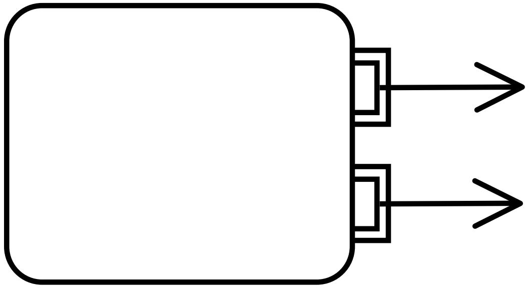
(EFFBD)



completion condition

completion condition

(UML 2)

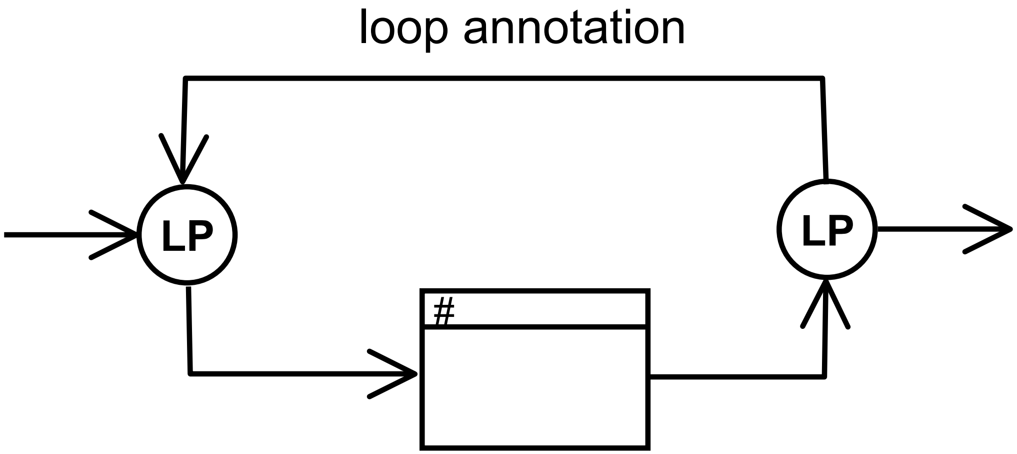


TBD: Postcondition
on parameter set

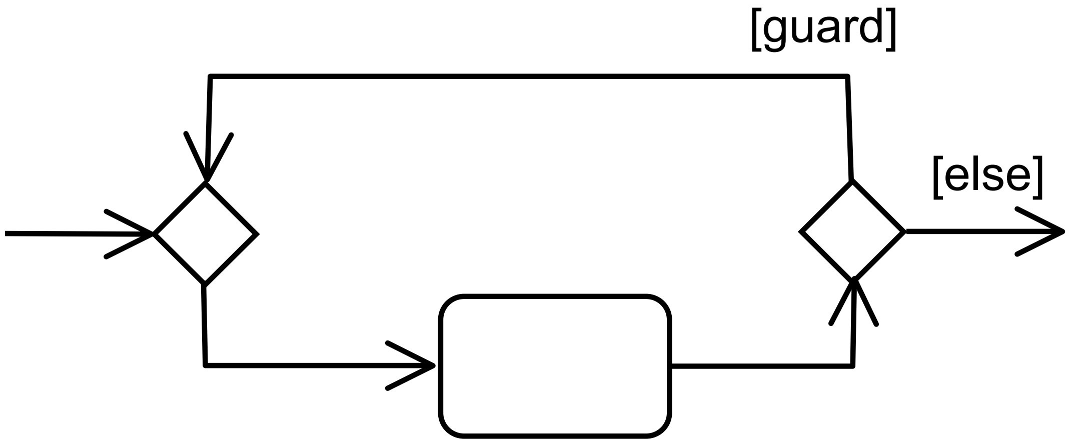
Cycles

- **EFFBD and UML 2 flows can have cycles in the flow graph.**

(EFFBD)

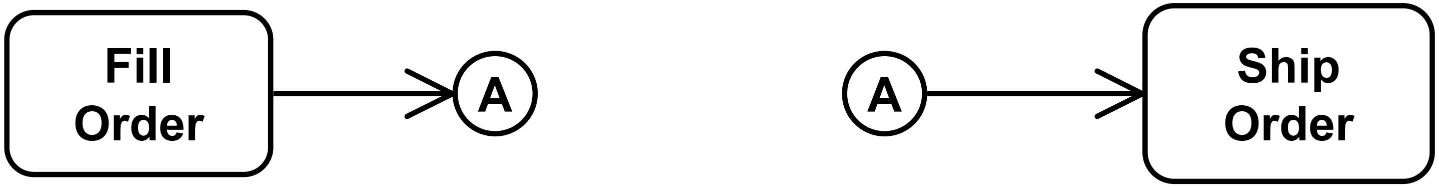


(UML 2)

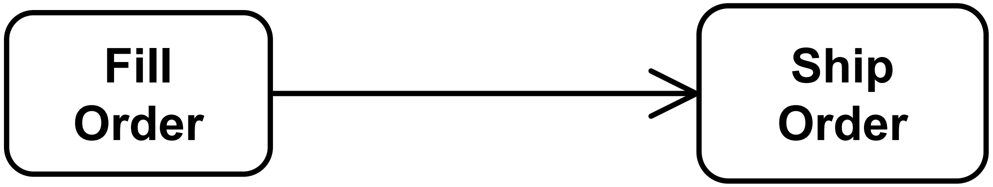


Edge Shortcuts

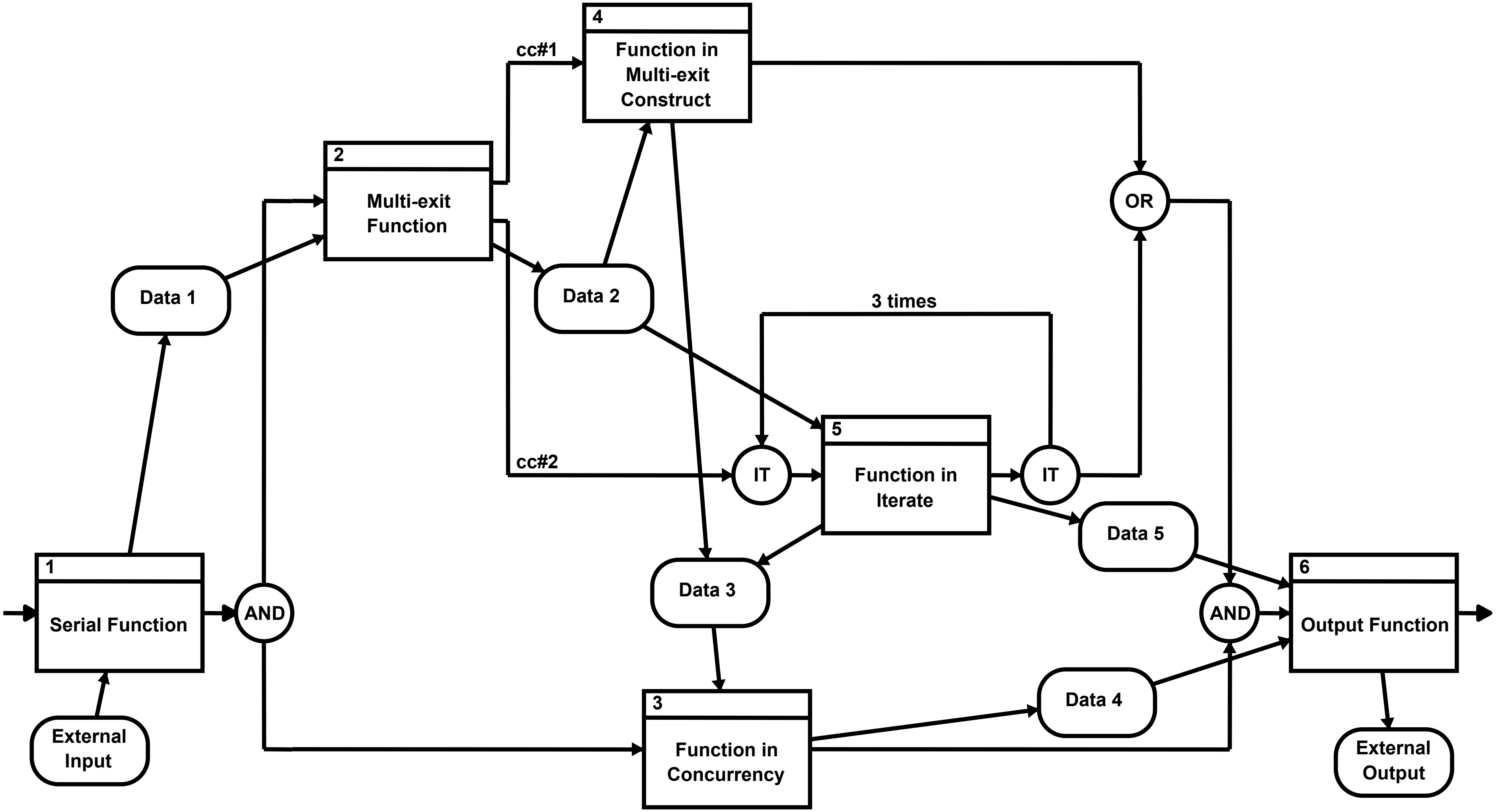
- Notational shorthand for long flow lines:



is equivalent to

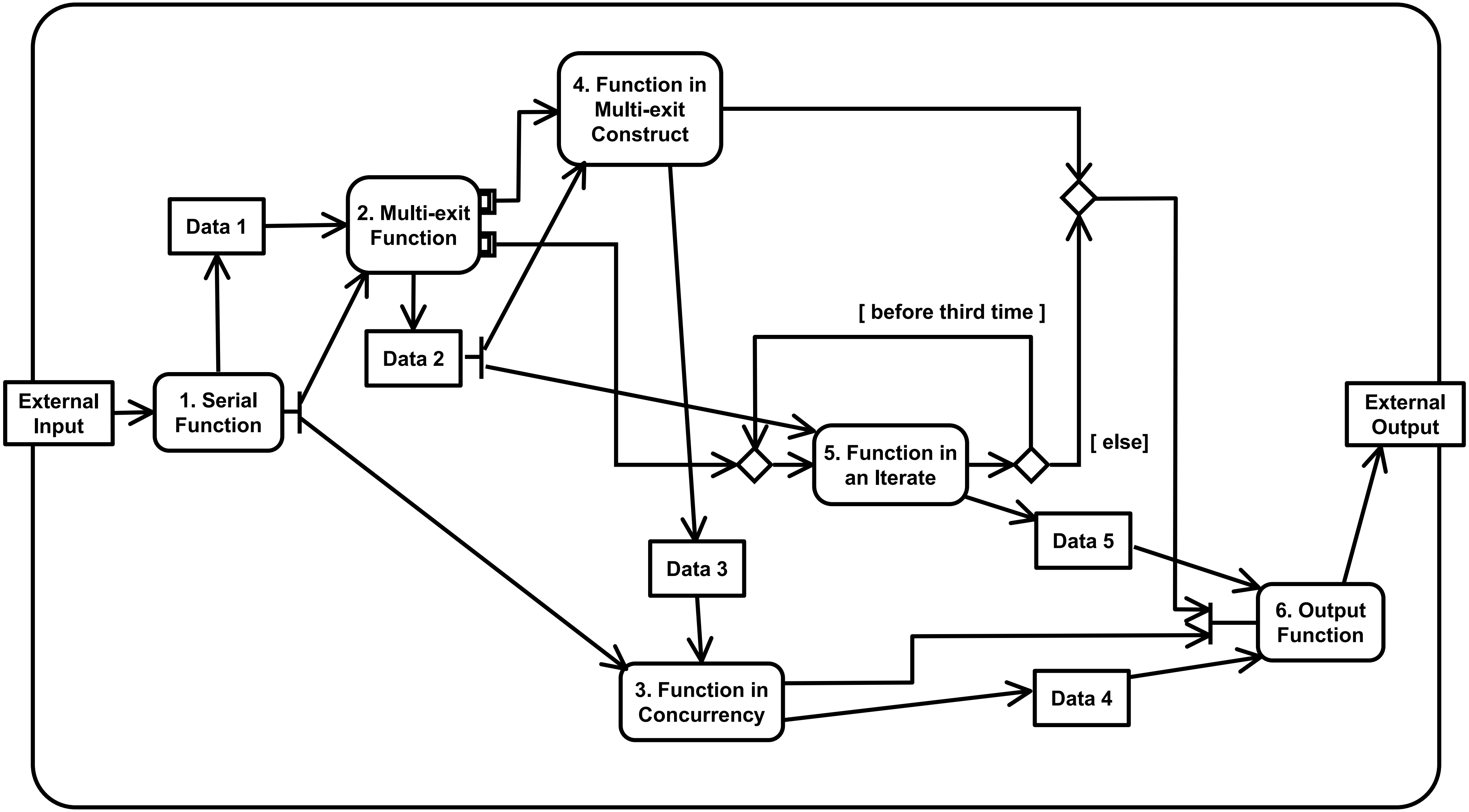


Example EFFBD



Adapted from Long, James, "Relationships between Common Graphical Representations in System Engineering", ViTech Corporation, www.vitechcorp.com

UML 2 Translation



To Be Addressed

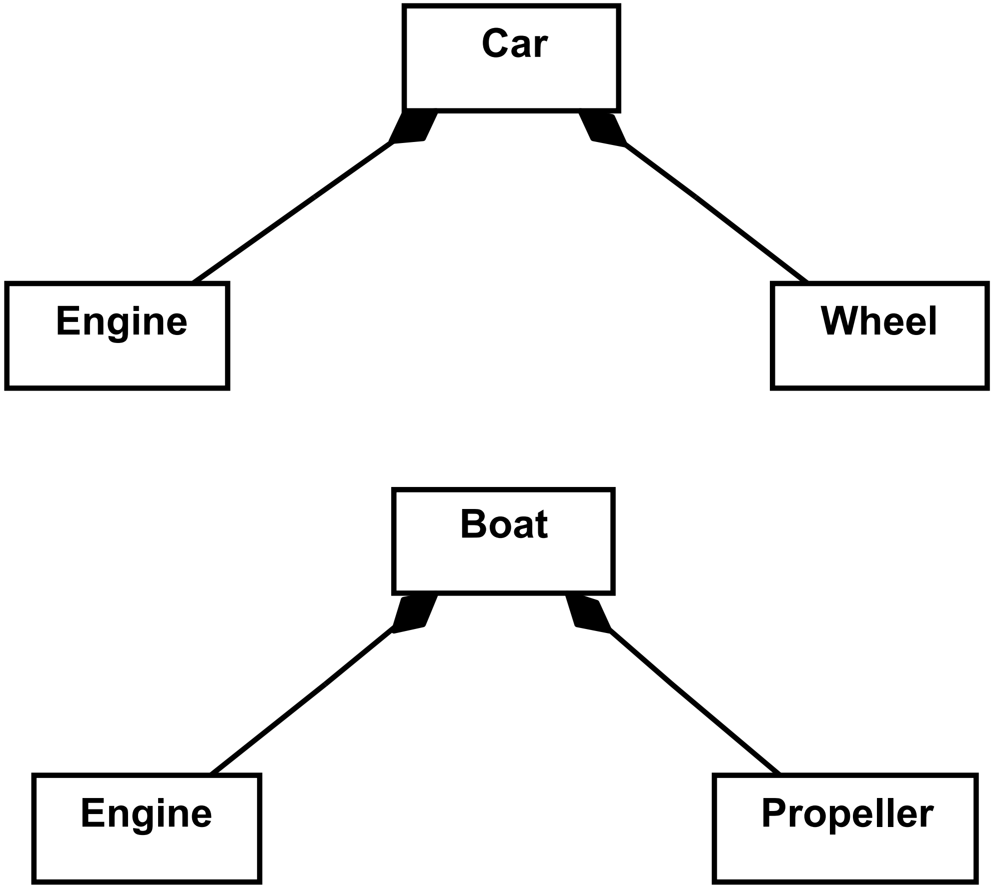
- Triggering and non-triggering inputs.
  - Distinguish required from streaming.
- Multi-exit, queuing on control.
  - Treat control as a kind of data.
- Completion conditions on multi-exit.
  - Add postconditions to UML 2 ParameterSet.
- Control/data flows that disable functions.
  - Extend control tokens.
- Iteration
  - Extend merge node.
- Continuous data flows.
  - Fine-grained token flow.

EFFBD ~ Activities

- Significant similarity between EFFBD and UML 2 Activities.
- Entry point for SE's into UML.
- Integrates with other UML features useful to SE:
  - Classes
  - Composition (Assembly)
  - Information Flow
  - Many other features not presented here.
- Details of EFFBD ←→ Activity translation at: http://www.u2-partners.org /outgoing/syseng/seu2pactivitymap.zip

Composition UML 1.x

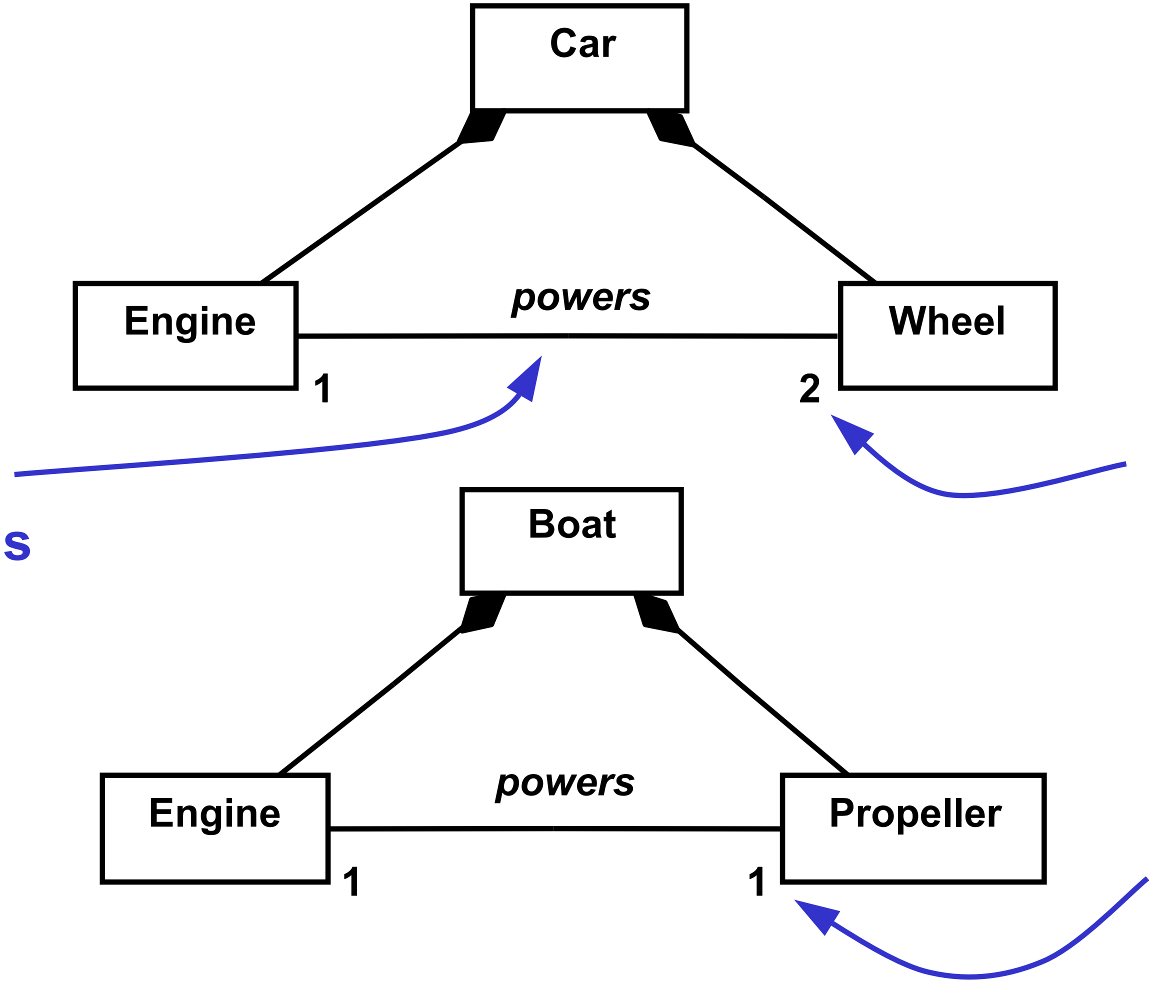
- **UML 1.x supported part-whole …**



Composition UML 1.x

- … but not part-part:

Associations are global



Power to wheels on other people's cars

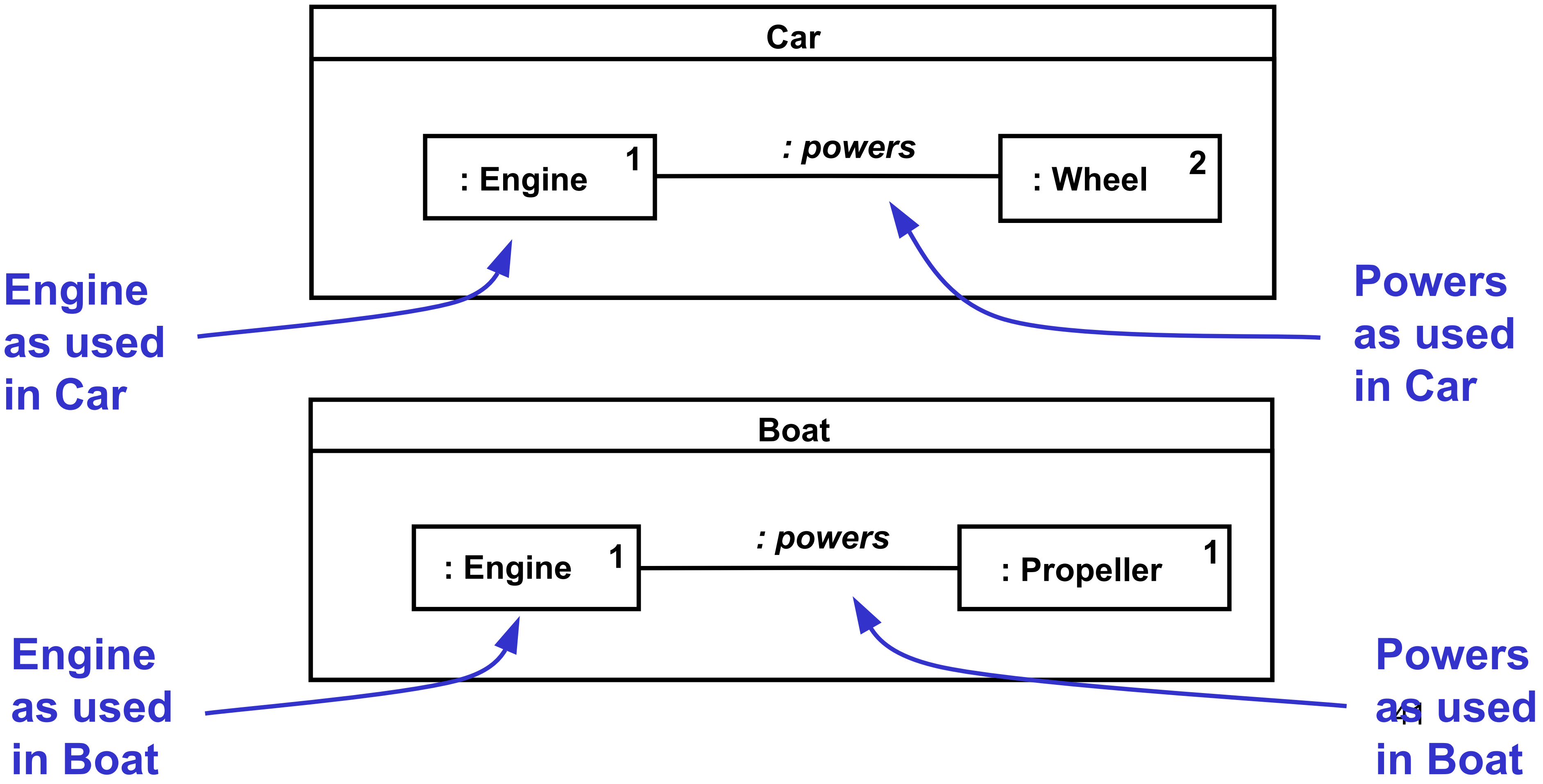
Wheels on boats

Propellers on cars

(not legal UML anyway)

Composition UML 2.0

- **UML 2 supports part-part in context:**



Engine as used in Car

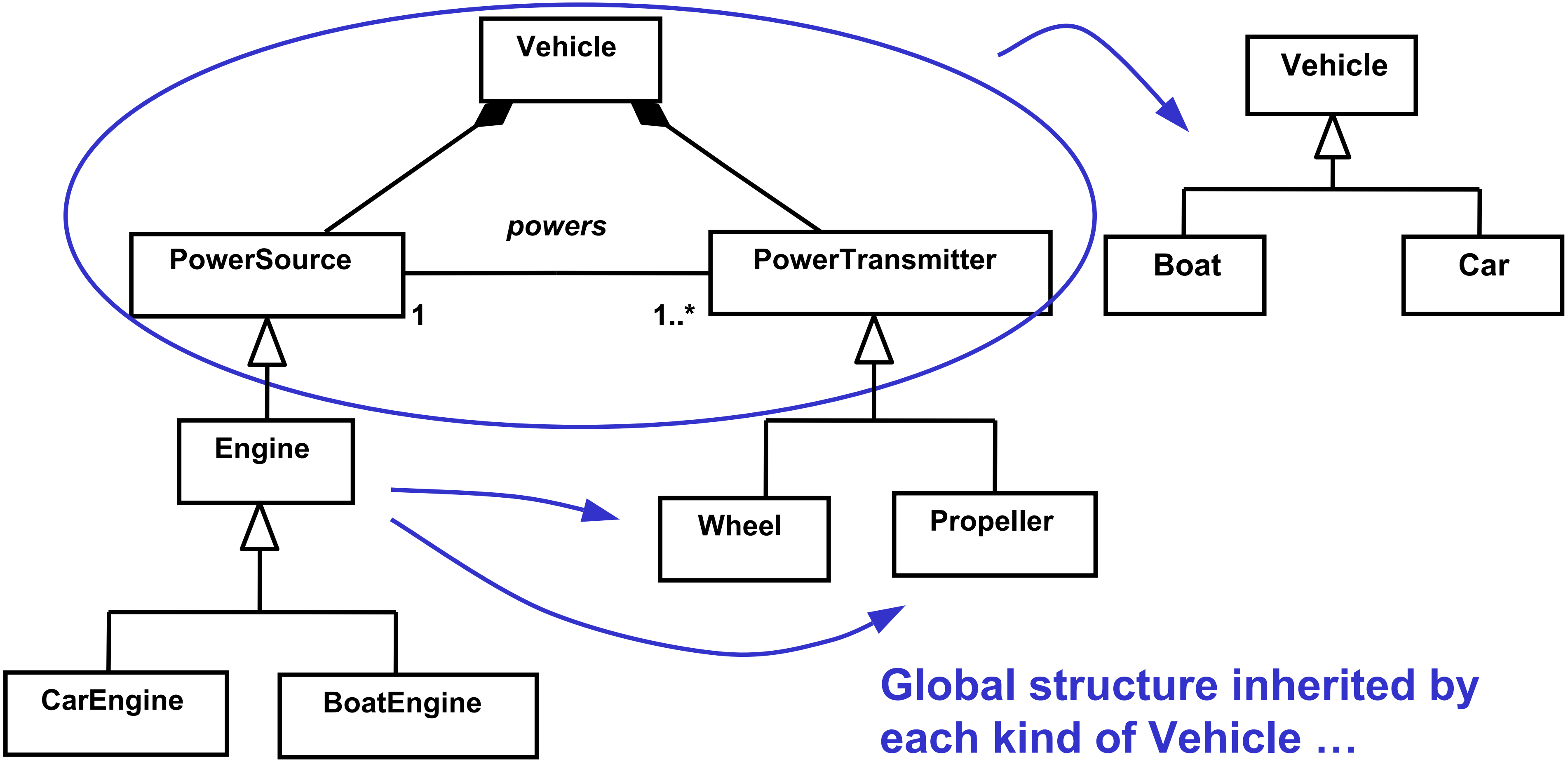
Powers as used in Car

Engine as used in Boat

Powers as used in Boat

Composition UML 2.0

- Enables better abstraction:

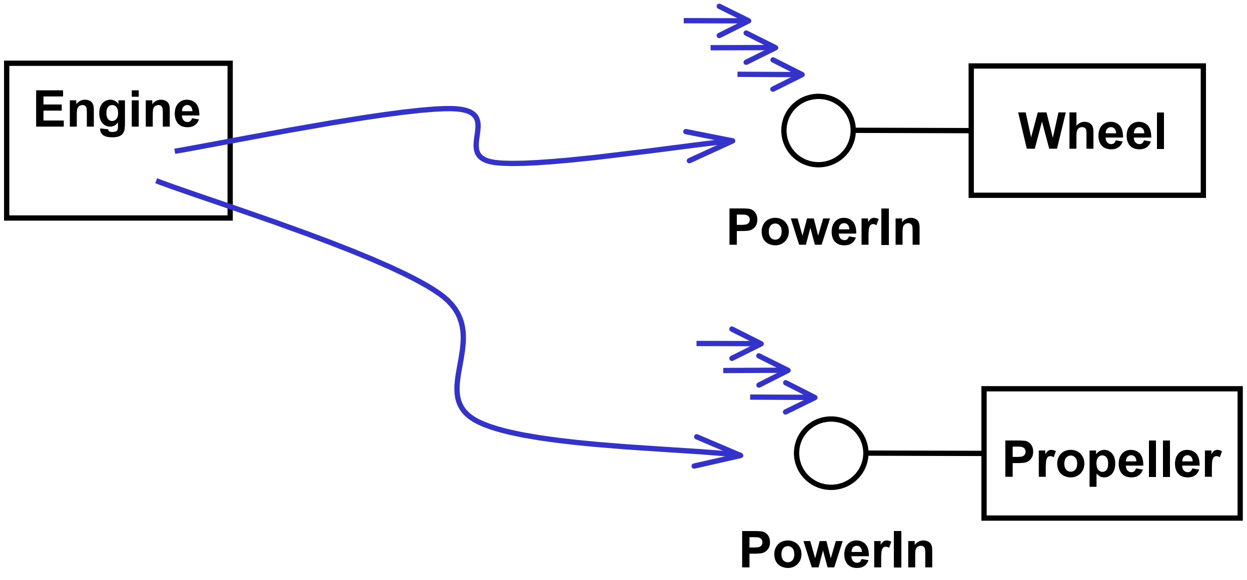


Global structure inherited by each kind of Vehicle …

… and constrained for each kind

Interfaces UML 1.x

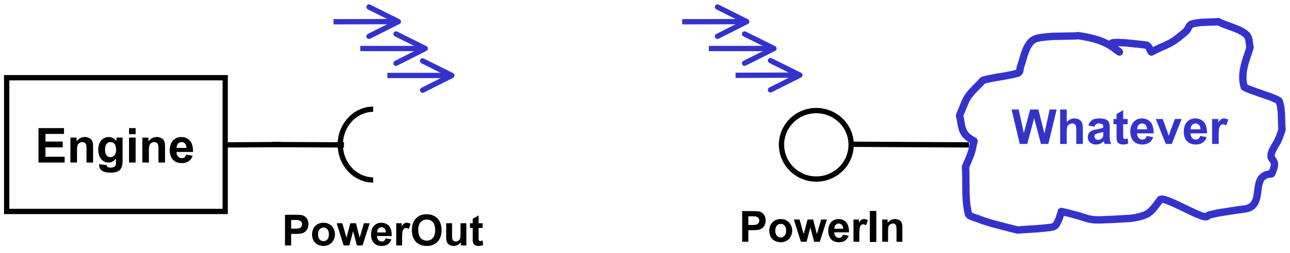
- UML 1.x supports interfaces, but only in one direction:

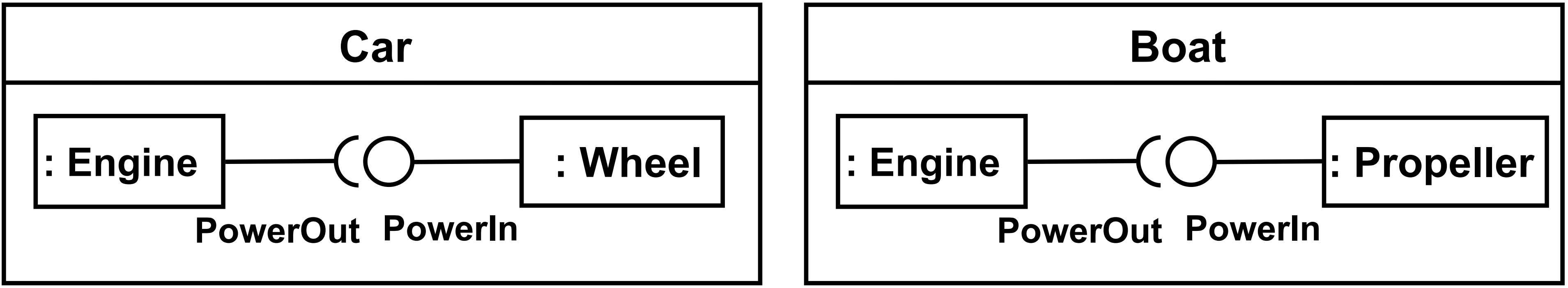


- Interface usage buried in client methods.

Interfaces UML 2.0

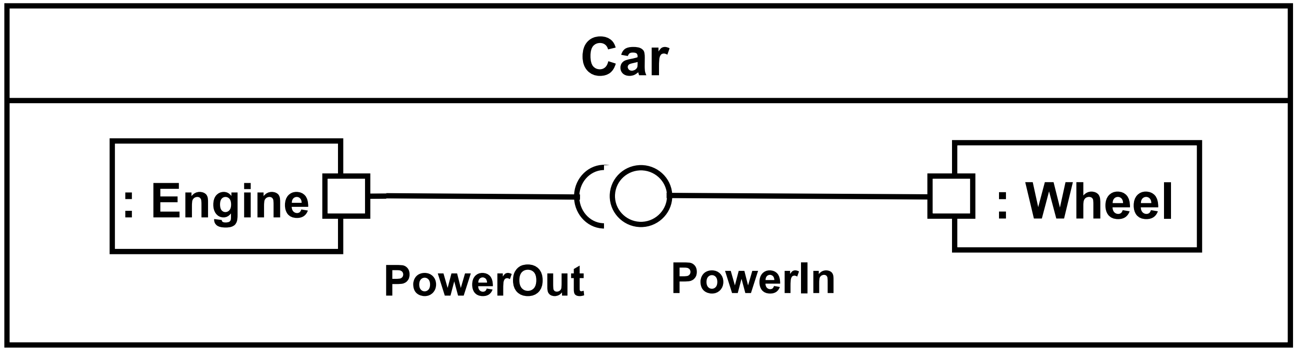
- **Bidirectional interfaces:**

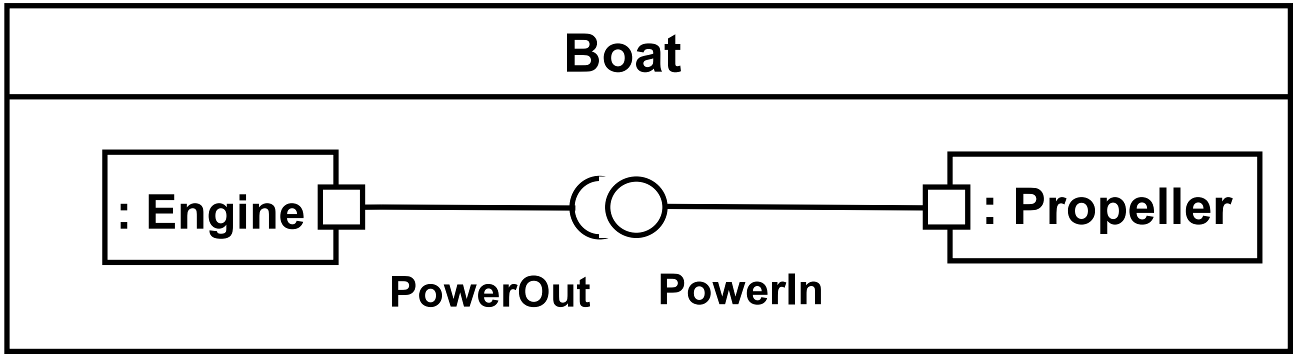




Composition 2.0 (Ports)

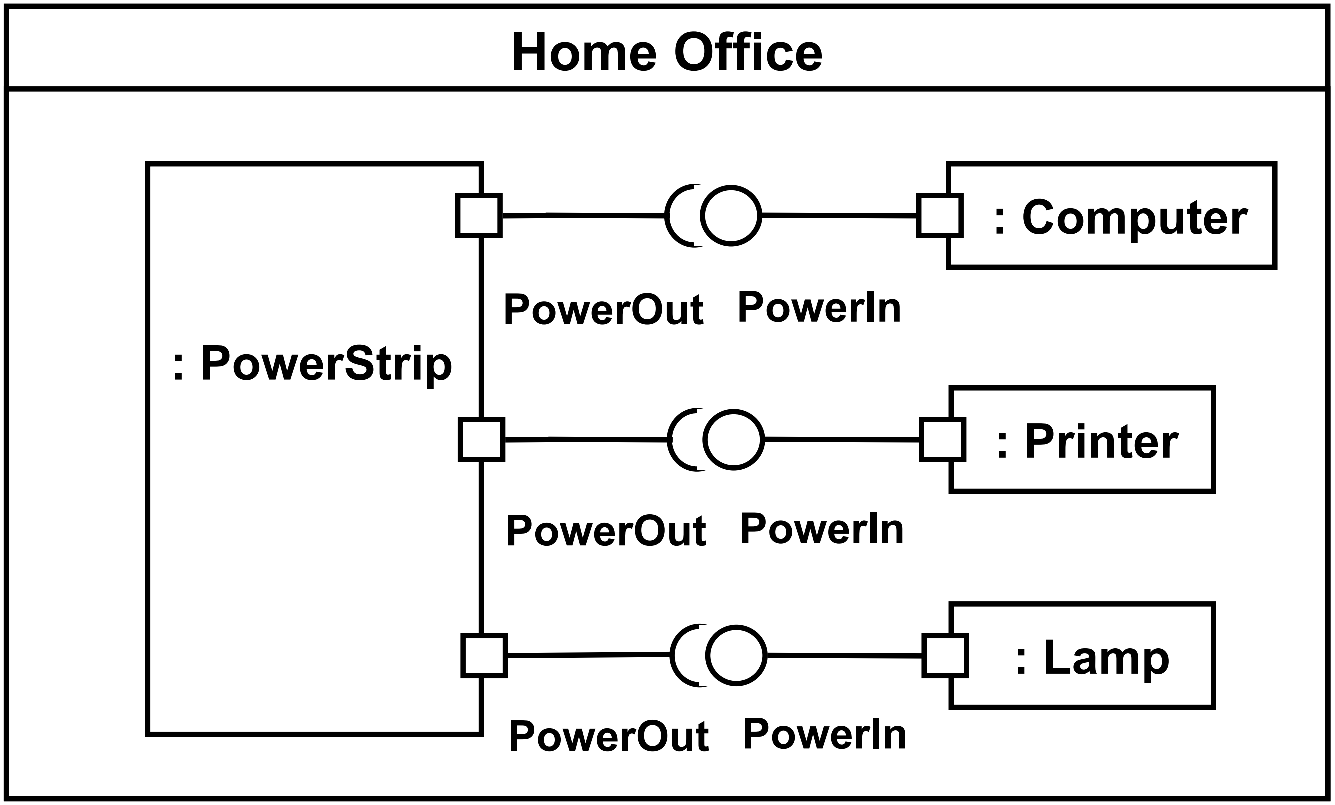
- Ports = public parts.





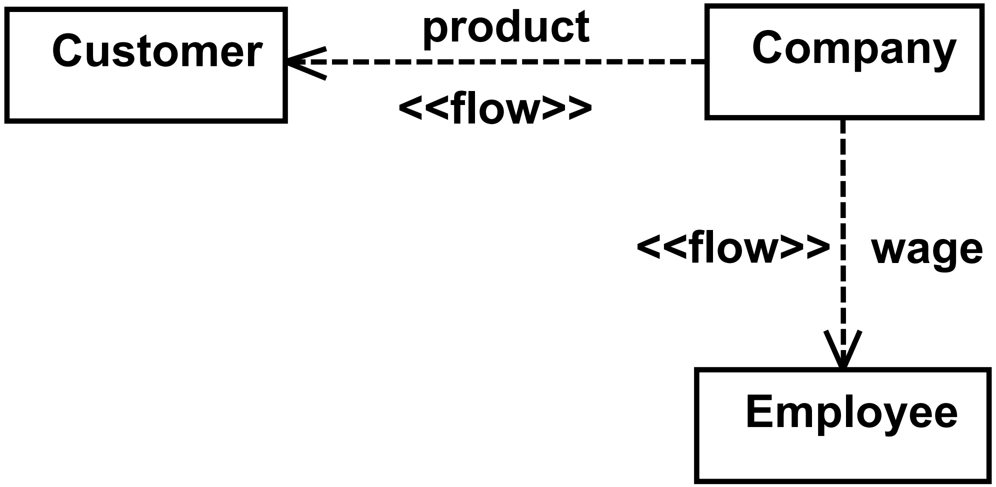
Composition 2.0 (Ports)

- **Multiple ports of the same type.**



Information Flow

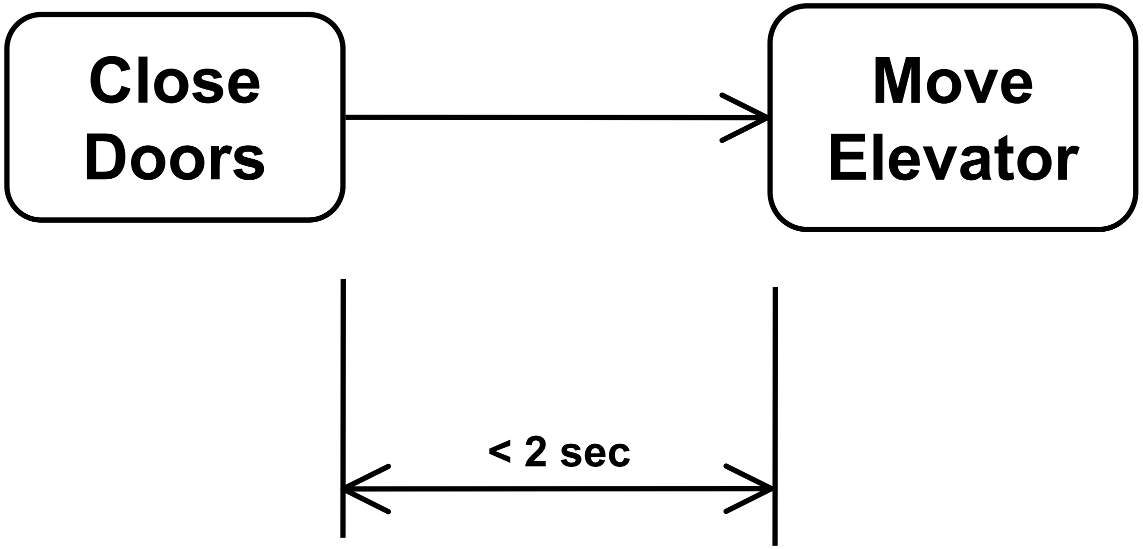
- Very abstract flow model.



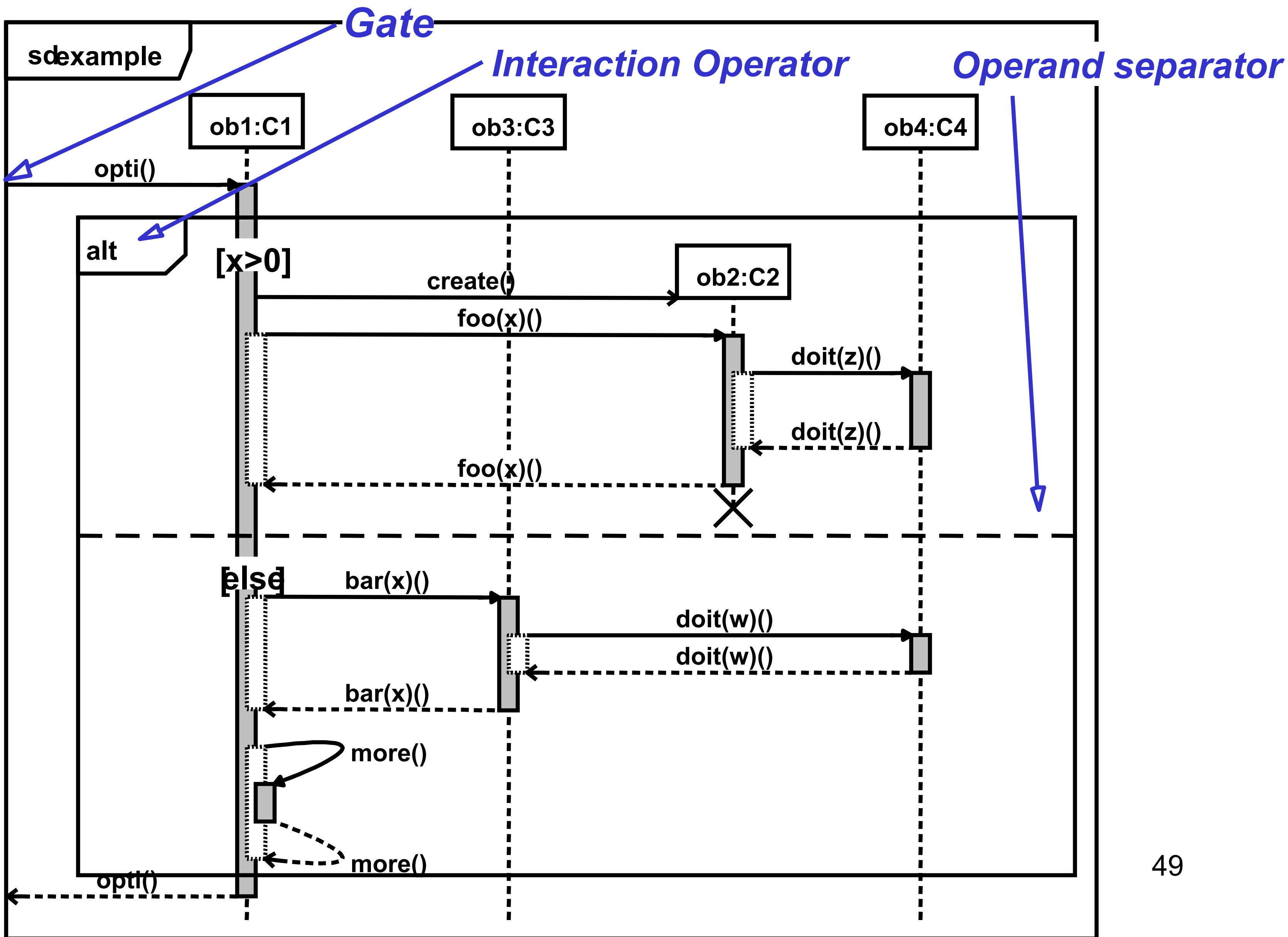
- Independent of message passing, parameters, etc, but can be tied to these.
- Applicable to Elaborated Context Diagrams

Time Model

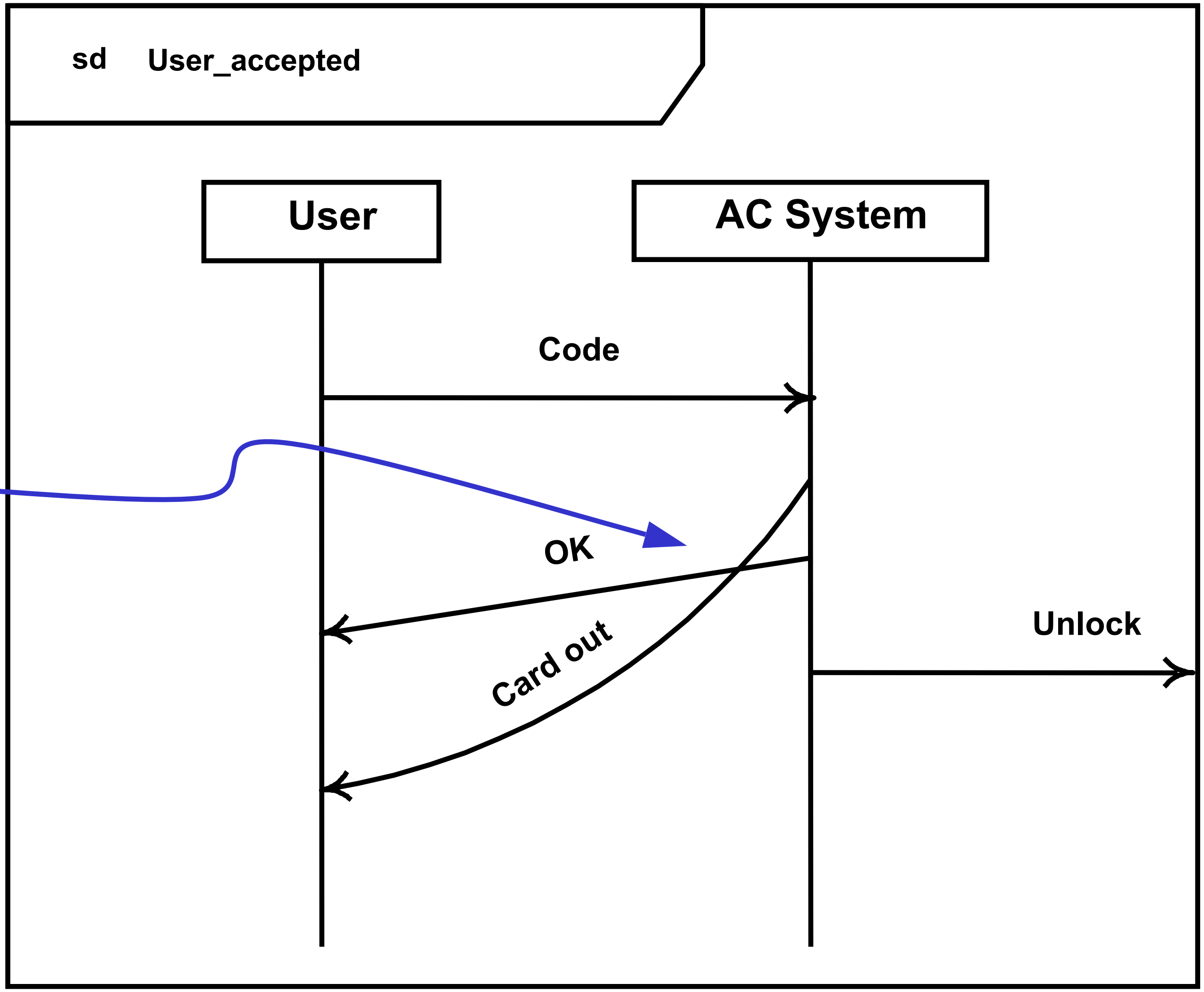
- Can be used to state constraints on processes:



Interaction Model



Interaction Model



Messages can overlap in time.

Deployment

- Support for general mappings between design elements, artifacts, and deployment targets.
- Communication paths between nodes.
  - Supports locality diagrams.

Summary

- UML is
  - wide lifecycle
  - applicable to multiple domains
  - a repository for multiple notations
- UML 2 adds new models useful to systems engineering …
- … in both structure and behavior.
- Latest draft of UML 2 submission: http://doc.omg.org/ad/03-03-02.
- Updates: http://www.omg.org/uml