On the Application of the Pi-Calculus to BPM

Formalizing & Simulating Interacting Processes

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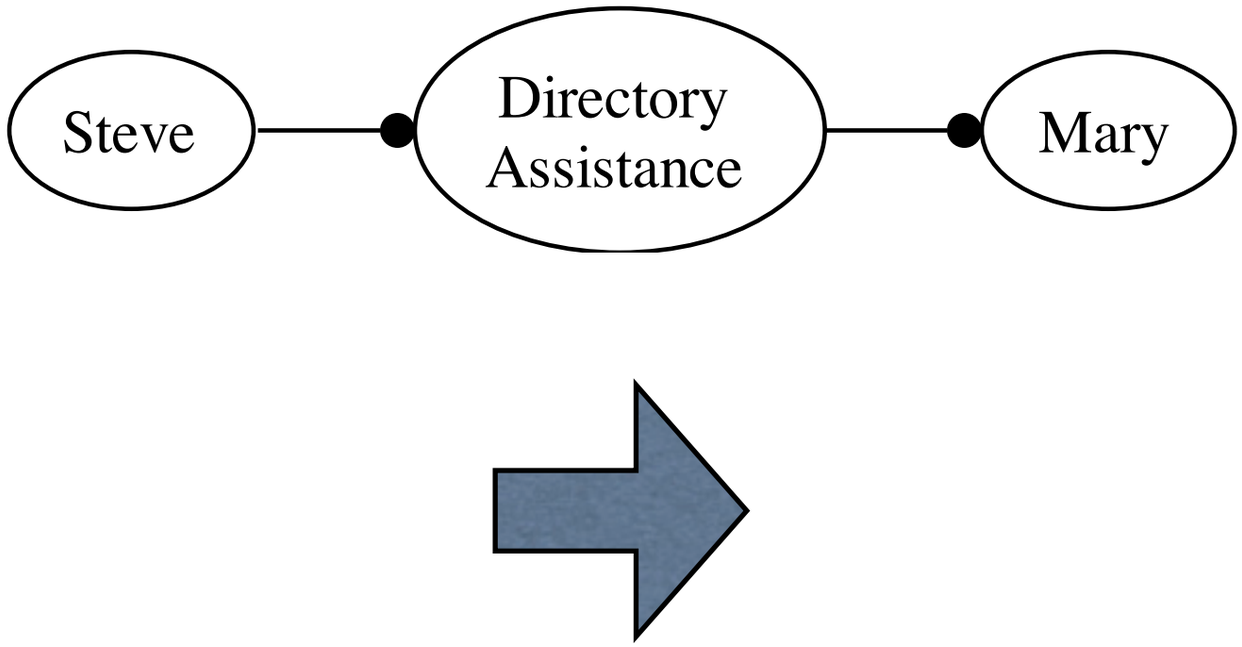
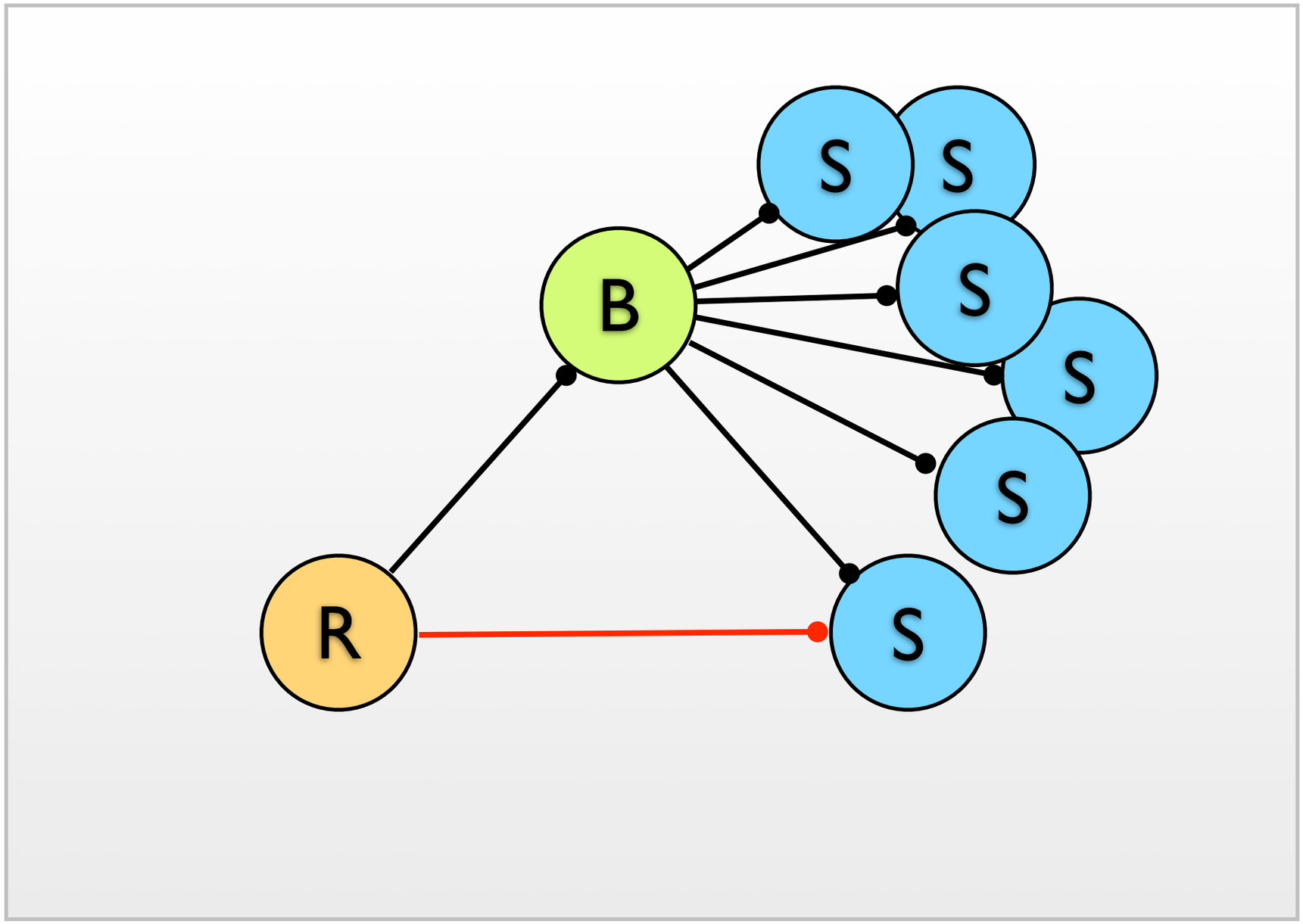
Motivation



Dynamic Systems



Pi-Calculus Link Passing Mobility

Outline

- The Pi-Calculus
- Processes (based on patterns)
- Interactions (among processes)
- Tooling (incl. live demo)

The Pi-Calculus

Grammar

- The Pi-Calculus consists of agents that use names for synchronization:

$$\pi ::= \overline{x}\langle\tilde{y}\rangle \mid x(\tilde{z}) \mid \tau \mid [x = y]\pi$$

$$P ::= M \mid P|P \mid \nu z\ P \mid \mathcal{K}(x_1, \ldots, x_n)$$
$$M ::= \mathbf{0} \mid \pi.P \mid M + M\ .$$

Link (Name) Passing

- Names can be sent via other names representing channels:

$$\overline{x}\langle a\rangle.\mathbf{0} \mid x(z).\mathbf{0}$$

- Received names can represent channels:

$$\overline{x}\langle a\rangle.a(y).\mathbf{0} \mid x(z).\overline{z}\langle c\rangle.\mathbf{0}$$

$$\xrightarrow{\overline{x}\langle a\rangle}$$

$$a(y).\mathbf{0} \mid \overline{a}\langle c\rangle.\mathbf{0}$$

Scope Extrusion

- The scope of restricted names can be extruded (i.e. extended):

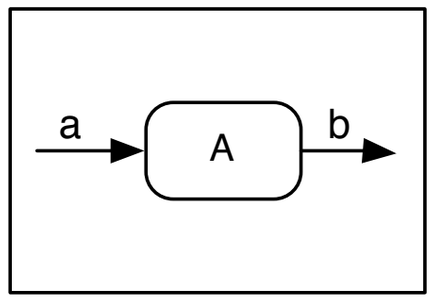
$$(\nu x\ \overline{a}\langle x\rangle.A) \mid a(y).B \xrightarrow{\overline{a}\langle x\rangle} \nu x\ (A \mid B\{^{x}/_{y}\})$$

Processes

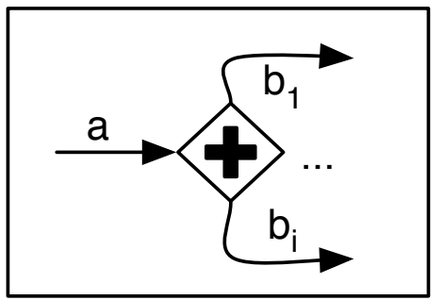
Process Patterns

- Business processes can be divided into patterns
- Common catalogue: Workflow Patterns
- We provide formal representations of these patterns
- Can be used to formally represent business processes

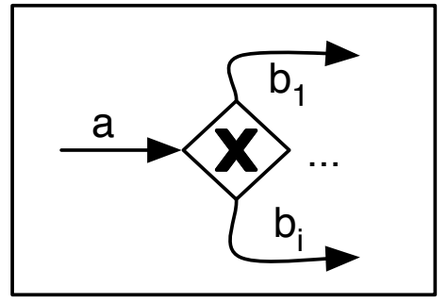
Basic Control Flow Patterns



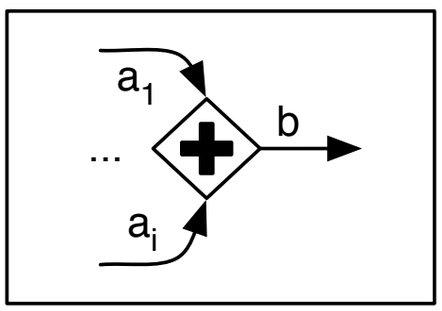
$$A \stackrel{def}{=} a.\langle\cdot\rangle.\overline{b}.\mathbf{0}$$



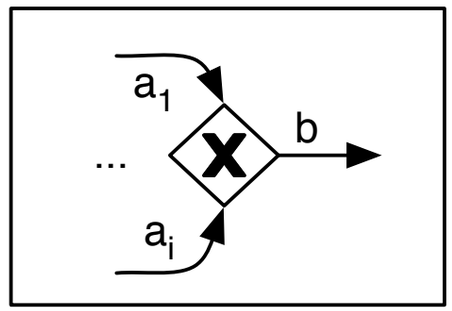
$$A \stackrel{def}{=} a.\langle\cdot\rangle.(\prod_{i=1}^{n} \overline{b_i}.\mathbf{0})$$



$$A \stackrel{def}{=} a.\langle\cdot\rangle.(\sum_{i=1}^{n} \overline{b_i}.\mathbf{0})$$

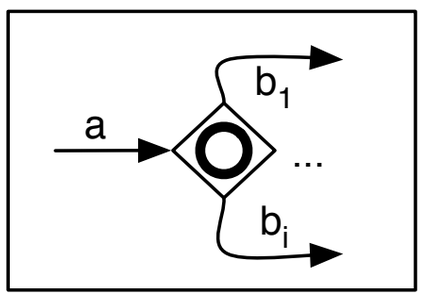


$$A \stackrel{def}{=} \{a_i\}_{i=1}^{n}.\langle\cdot\rangle.\overline{b}.\mathbf{0}$$

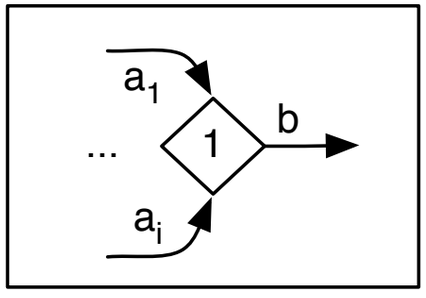


$$A \stackrel{def}{=} \sum_{i=1}^{n} a_i.\langle\cdot\rangle.\overline{b}.\mathbf{0}$$

Advanced Control Flow Patterns (subset)



$$A \stackrel{def}{=} \nu c\, a.\langle\cdot\rangle.(\prod_{i=1}^{n}(\overbrace{\overline{b_i}.\mathbf{0}}^{enable} + \overbrace{c.\mathbf{0}}^{\text{cancel}}) \mid \{\overline{c}\}_{i=1}^{n-1}.\mathbf{0})$$



$$A \stackrel{def}{=} \nu h\, \nu e\, (A_1 \mid A_2)$$

$$A_1 \stackrel{def}{=} \prod_{i=1}^{m} a_i.\overline{h}.\mathbf{0}$$

$$A_2 \stackrel{def}{=} h.\overline{e}.\{h\}_1^{m-1}.A \mid e.\langle\cdot\rangle.\overline{b}.\mathbf{0}$$

More Patterns

- Arbitrary Cycles

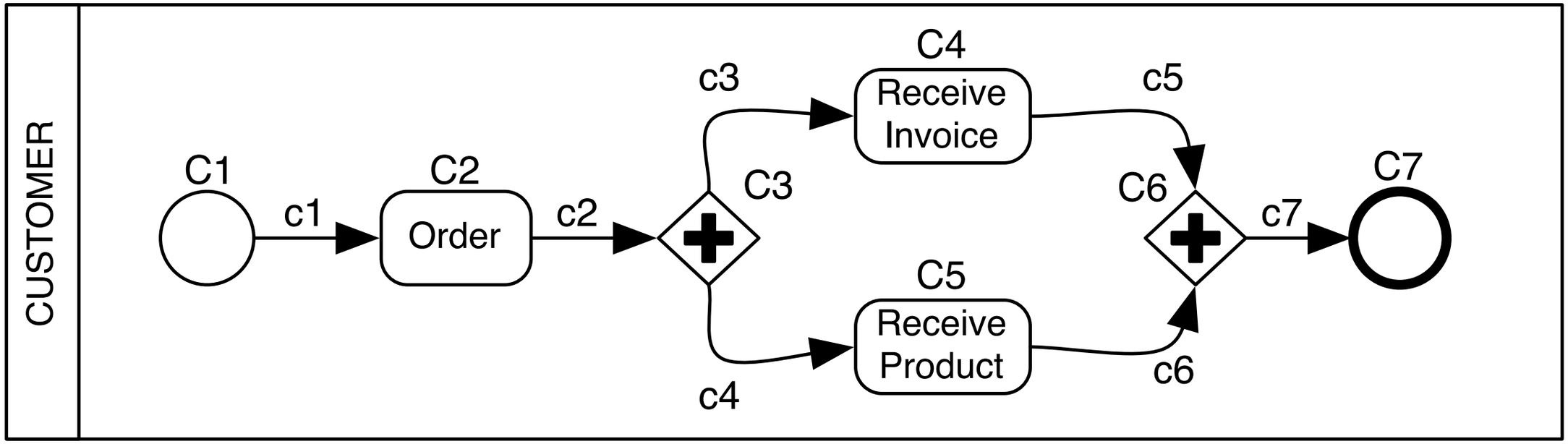
$A \stackrel{def}{=} a.\langle\cdot\rangle.\overline{b}.\mathbf{0}$ becomes $A \stackrel{def}{=} a.(\langle\cdot\rangle.\overline{b}.\mathbf{0} \mid A)$

- Deferred Choice
- Milestone
- ...

Algorithm

- Mapping BPDs to Pi-Calculus (sketch):
  - Each flow object is represented by an agent identifier according to the semantics of the pattern it represents
  - Each sequence flow is represented by a restricted name used as pre- and postcondition for the flow objects
  - A global agent for the whole system is defined

Example



$$C1 \stackrel{def}{=} \langle\cdot\rangle.\overline{c1}.\mathbf{0}$$

$$C2 \stackrel{def}{=} c1.\langle\cdot\rangle.\overline{c2}.\mathbf{0}$$

$$C3 \stackrel{def}{=} c2.\langle\cdot\rangle.(\overline{c3}.\mathbf{0} \mid \overline{c4}.\mathbf{0})$$

$$C4 \stackrel{def}{=} c3.\langle\cdot\rangle.\overline{c5}.\mathbf{0}$$

$$C5 \stackrel{def}{=} c4.\langle\cdot\rangle.\overline{c6}.\mathbf{0}$$

$$C6 \stackrel{def}{=} c5.c6.\langle\cdot\rangle.\overline{c7}.\mathbf{0}$$

$$C7 \stackrel{def}{=} c7.\langle\cdot\rangle.\mathbf{0}$$

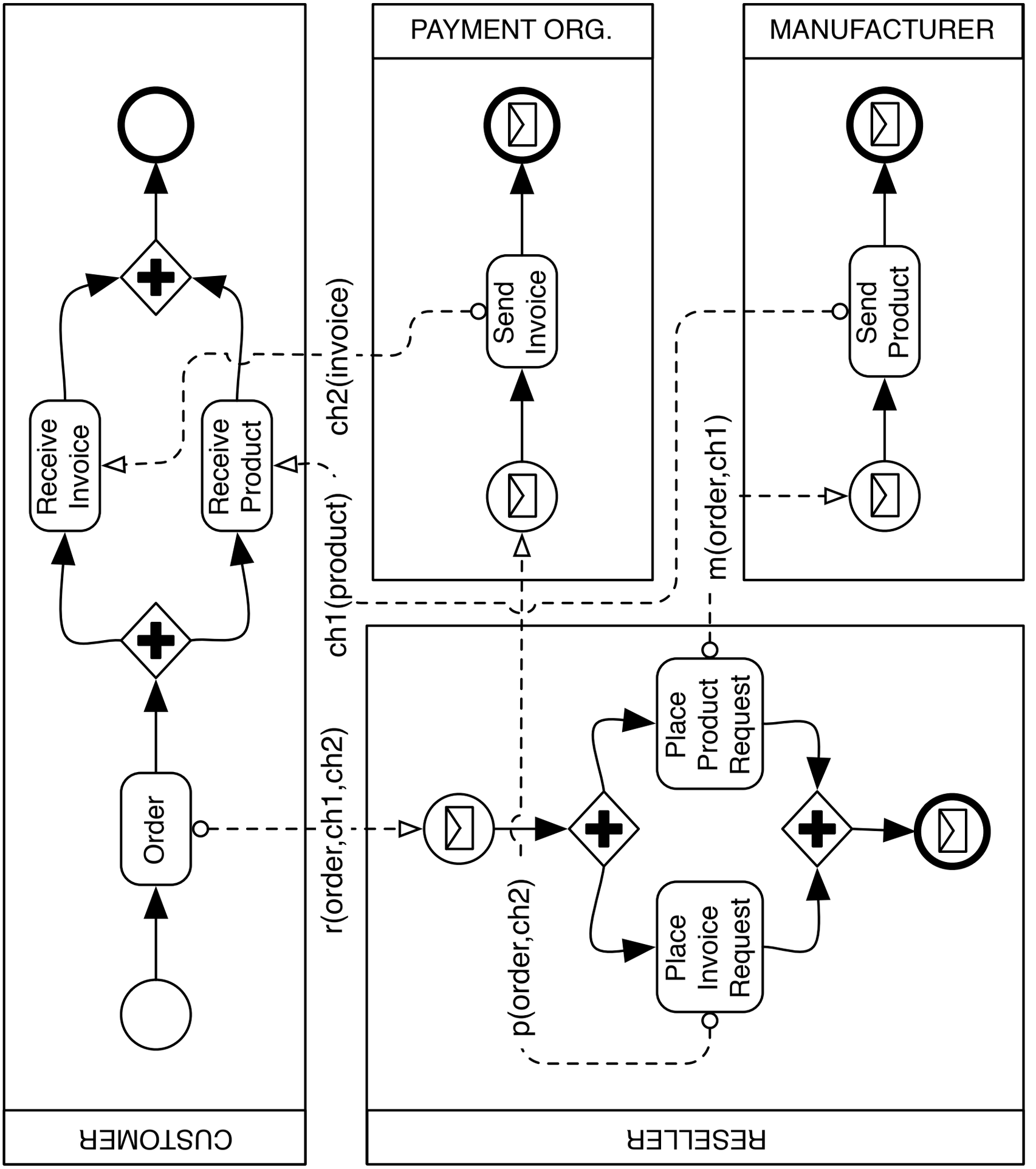
$$N \stackrel{def}{=} (\nu c1, \ldots, c7) \prod_{i=1}^{7} Ci$$

Interactions

Interactions

- Formalized business processes can be enhanced for interactions
- Questions:
  - How to represent message flows?
  - How to represent dynamic binding?
  - How to represent correlations?

Example


CUSTOMER
RESELLER
PAYMENT ORG.
MANUFACTURER
Order
Receive Invoice
Receive Product
Place Invoice Request
Place Product Request
Send Invoice
Send Product
r(order,ch1,ch2)
p(order,ch2)
ch1(product)
ch2(invoice)
m(order,ch1)

Dynamic Binding and Correlations

- Idea:
  - Pi-Calculus names are used to represent message flows between a number of processes
- A combination of link passing mobility and scope extrusions realizes dynamic binding directly

Correlations

- A can invoke B several times
- Correlations managed by the restricted name ch:

$$A \stackrel{def}{=} \nu ch\ \overline{b}\langle ch\rangle.(ch(r).A' \mid A)$$

$$B \stackrel{def}{=} \nu r\ b(ch).(\tau.\overline{ch}\langle r\rangle.\mathbf{0} \mid B)$$

Send Interaction Pattern

- Send:

$$A \stackrel{def}{=} \langle \cdot \rangle . \overline{ch} \langle msg \rangle . \mathbf{0}$$

- Static binding:

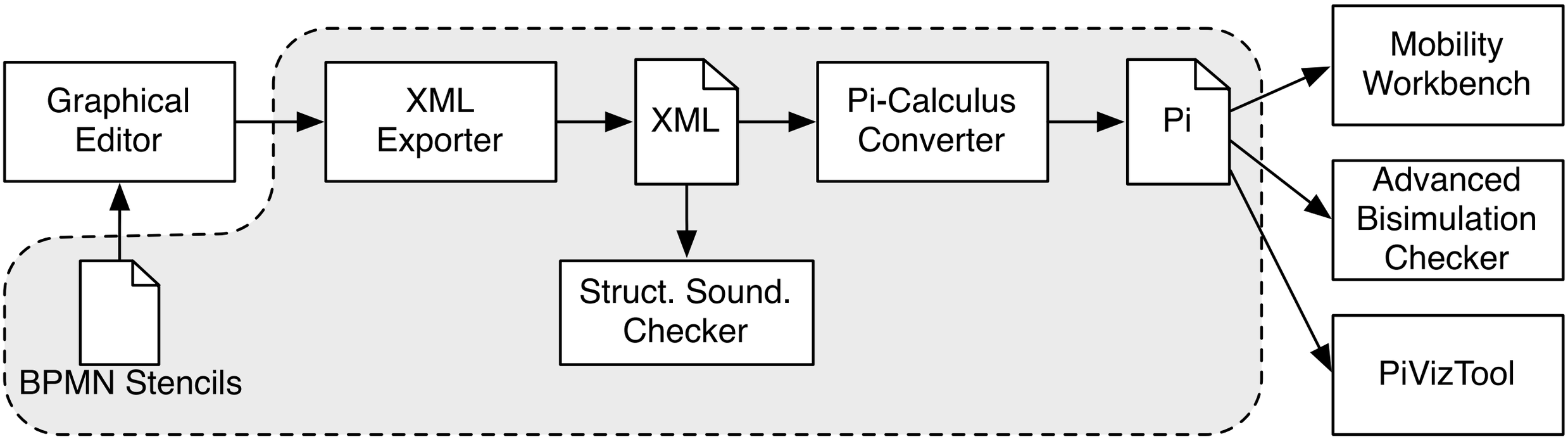
$$I \stackrel{def}{=} \nu ch \ (A \mid E)$$

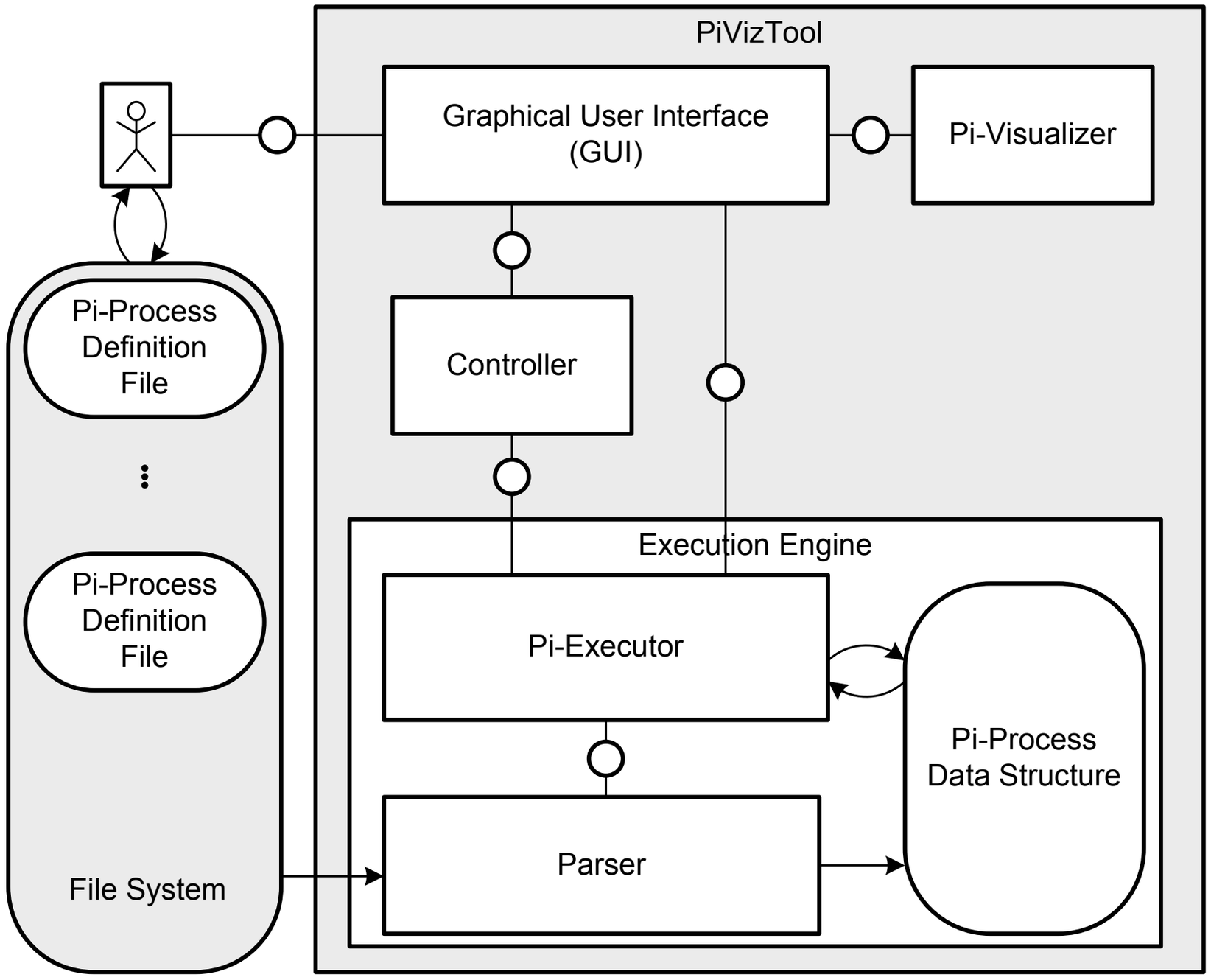
- Dynamic binding:

$$I \stackrel{def}{=} \nu lookup \ (lookup(ch).A \mid \mathbb{E})$$

Tooling

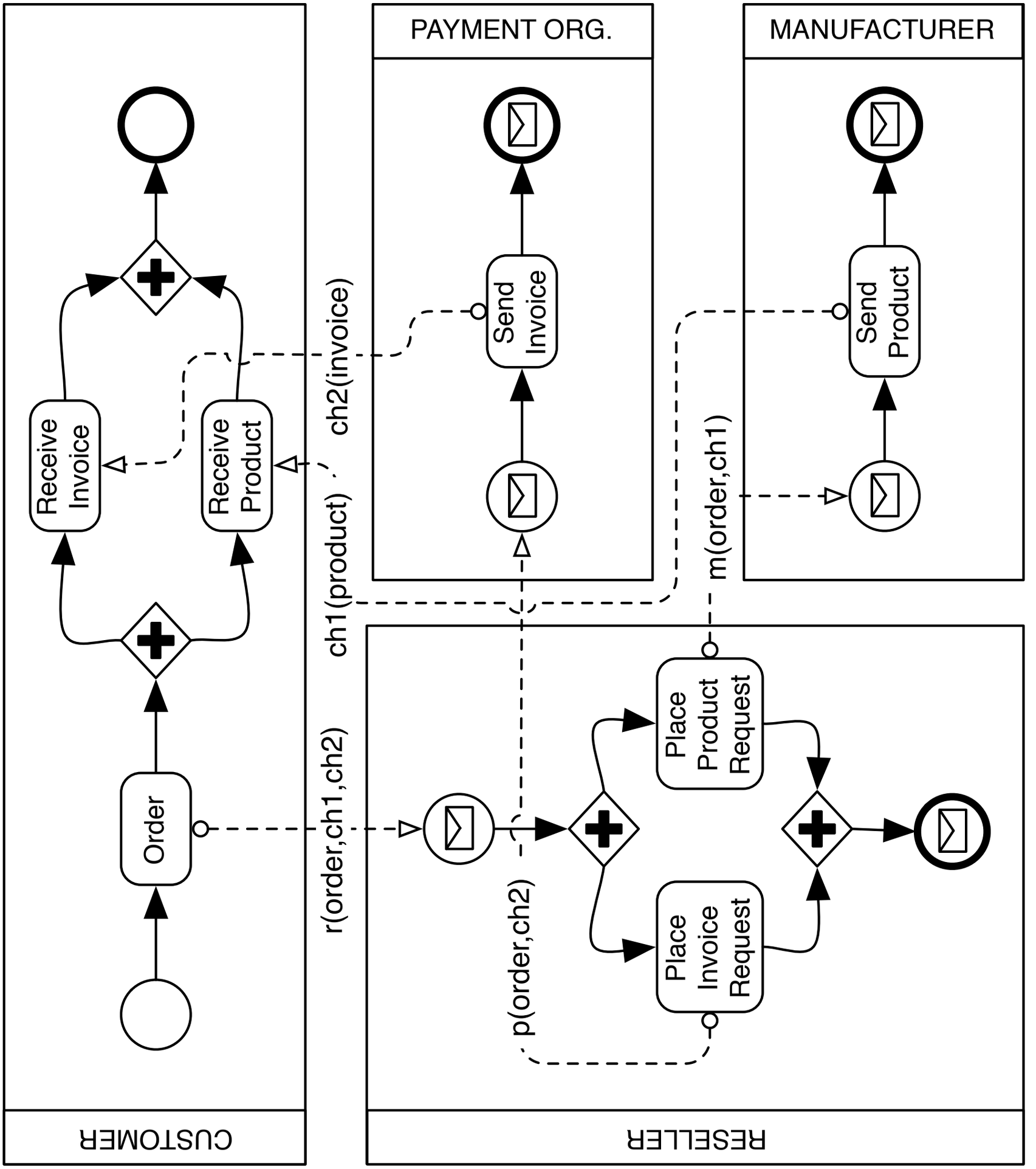
Tool Chain


Graphical Editor
XML Exporter
XML
Pi-Calculus Converter
Pi
Mobility Workbench
Advanced Bisimulation Checker
PiVizTool
Struct. Sound. Checker
BPMN Stencils


PiVizTool
Graphical User Interface
(GUI)
Pi-Visualizer
Controller
Execution Engine
Pi-Executor
Pi-Process
Data Structure
Parser
Pi-Process
Definition
File
Pi-Process
Definition
File
File System

PiVizTool

Example


CUSTOMER
RESELLER
PAYMENT ORG.
MANUFACTURER
Order
Receive Invoice
Receive Product
Place Invoice Request
Place Product Request
Send Invoice
Send Product
r(order,ch1,ch2)
p(order,ch2)
ch1(product)
ch2(invoice)
m(order,ch1)

Conclusion

Summary

- We introduced how the pi-calculus can be applied to BPM
  - Processes based on formalized patterns
  - Interaction among them, incl. dynamic binding
  - Tooling

Further Readings

[1]**Frank Puhlmann**, Mathias Weske: *Using the Pi-Calculus for Formalizing Workflow Patterns*. In W.M.P. van der Aalst, B. Benatallah, F. Casati, and F. Curbera (Eds.): Proceedings of the 3rd International Conference on Business Process Management (BPM 2005), volume 3649 of LNCS, Nancy, France, Springer-Verlag (2005) 153-168

[2]Hagen Overdick, **Frank Puhlmann**, Mathias Weske: *Towards a Formal Model for Agile Service Discovery and Integration*. In K. Verma, A. Sheth, M. Zaremba, and C. Bussler (Eds.): Proceedings of the International Workshop in Dynamic Web Processes (DWP 2005), Amsterdam, The Netherlands, IBM technical report RC23822 (2005)

[3]**Frank Puhlmann**: *Why do we actually need the Pi-Calculus for Business Process Management?* In W. Abramowicz and H. Mayr (Eds.): Proceedings of the 9th International Conference on Business Information Systems (BIS 2006), volume P-85 of LNI, Klagenfurt, Austria, Gesellschaft fuer Informatik (2006) 77-89

[4]**Frank Puhlmann**, Mathias Weske: *Investigations on Soundness Regarding Lazy Activities*. In S. Dustdar, J.L. Fiadeiro and A. Sheth (Eds.): Proceedings of the 4th International Conference on Business Process Management (BPM 2006), volume 4102 of LNCS, Vienna, Austria, Springer-Verlag (2006) 145-160

[5]**Frank Puhlmann**: *A Tool Chain for Lazy Soundness*. Demo Session of the 4th International Conference on Business Process Management, CEUR Workshop Proceedings Vol. 203, Vienna, Austria (2006) 9-16

[6]Gero Decker, **Frank Puhlmann**, Mathias Weske: *Formalizing Service Interactions*. In S. Dustdar, J.L. Fiadeiro and A. Sheth (Eds.): Proceedings of the 4th International Conference on Business Process Management (BPM 2006), volume 4102 of LNCS, Vienna, Austria, Springer-Verlag (2006) 414-419

[7]**Frank Puhlmann**: *A Unified Formal Foundation for Service Oriented Architectures*. In M. Weske and M. Nuettgens (Eds.): EMISA 2006, volume P-95 of LNI, Hamburg, Germany (2006) 7-19

[8]**Frank Puhlmann**: *On the Suitability of the Pi-Calculus for Business Process Management*. In Technologies for Business Information Systems. Springer-Verlag (2007) 51-62

[9]**Frank Puhlmann**, Mathias Weske: *Interaction Soundness for Service Orchestrations*. In A. Dan and W. Lamersdorf (Eds.): Proceedings of the 4th International Conference on Service Oriented Computing (ICSOC 2006), volume 4294 of LNCS, Chicago, USA, Springer-Verlag (2006) 302-313

[10]Anja Bog, **Frank Puhlmann**: A Tool for the Simulation of Pi-Calculus Systems. Available at Online.

Thank You!