Breathing Life into Models: The Next Generation of Enterprise Modeling

Peter Fettke
Saarland University and
German Research Center for Artificial Intelligence (DFKI), Germany

Keynote, ICSOFT 2022
Lisbon, Portugal, July 12, 2022

Breathing Life into Models: The Next Generation of Enterprise Modeling

Peter Fettke
Saarland University and
German Research Center for Artificial Intelligence (DFKI), Germany

Wolfgang Reisig
Humboldt-Universität zu Berlin, Germany

Keynote, ICSOFT 2022
Lisbon, Portugal, July 12, 2022

UNIVERSITÄT DES SAARLANDES

DFKI

HUMBOLDT-UNIVERSITÄT ZU BERLIN

Agenda

1. Preliminary Remarks
2. Future of Enterprise Modeling
3. Conclusions

Enterprise modeling in 1993: Hasso Plattner and Klaus Besier pose with the SAP ERP Reference Model (as a marketing instrument)

Enterprise modeling in 1993: Hasso Plattner and Klaus Besier pose with the SAP ERP Reference Model (as a marketing instrument)

UNIVERSITÄT DES SAARLANDES

Historical sidenote

- 1990 first Honorary Doctorship from Saarland University
- 1994 first Honorary Professorship for business informatics from Saarland University
- 1997 Honorary Senator of Saarland University

Picture of the ceremony

President of Saarland University (Günther Hönn) and Plattner in 1997

Enterprise modeling today

source: Moody (2005)

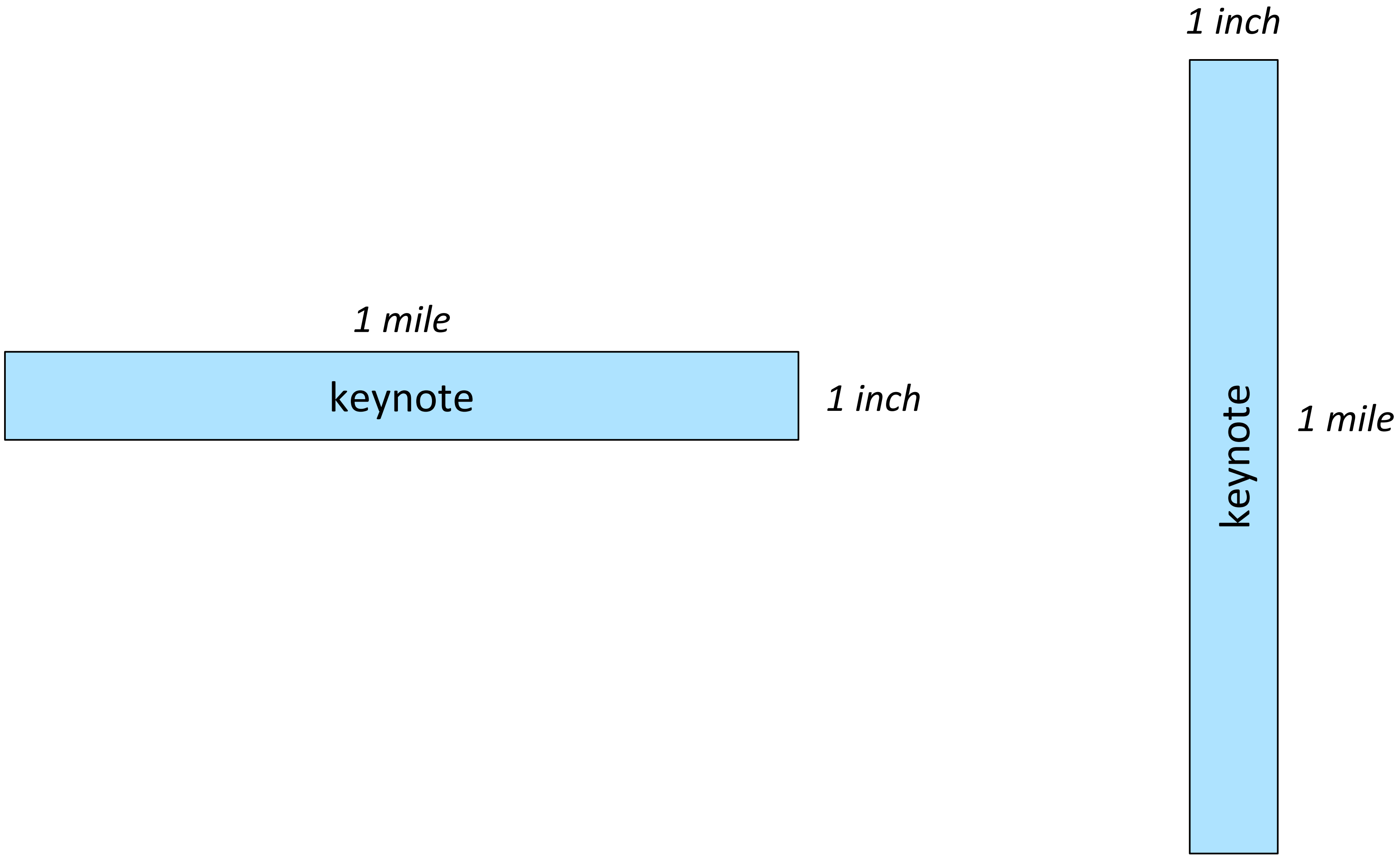
Future of enterprise modeling: width vs. depth

1 mile

keynote *1 inch*

mile wide and inch deep

Future of enterprise modeling: width vs. depth



mile wide and inch deep

inch wide and mile deep
(this keynote)

Agenda

1. Preliminary Remarks
2. Future of Enterprise Modeling
3. Implications and Conclusions

What is the most fundamental concept of enterprise modeling?

Change ("everything flows")!
But: What is "change"? And how to study "change"?

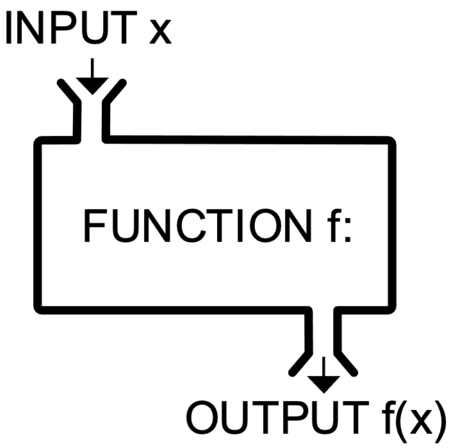
2005

2013

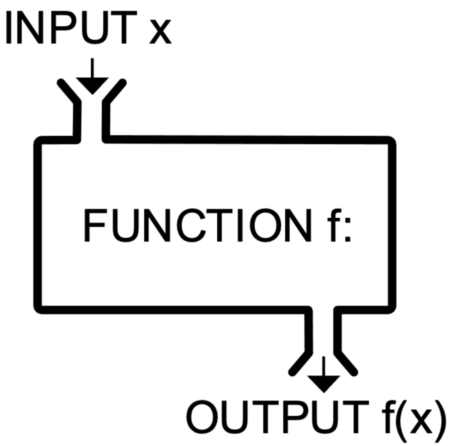
2020

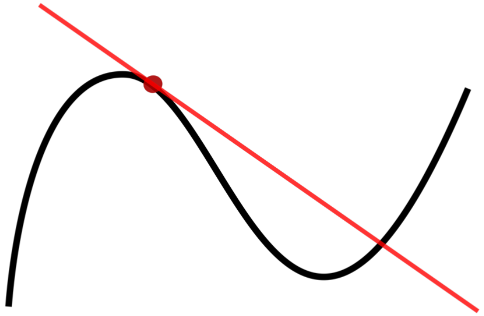
St. Peter's Square, Vatican City

Most basic understanding of change

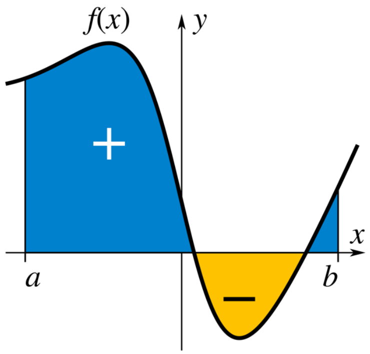


The calculus allows to study change





differential calculus



integral calculus

“The calculus was the first achievement of modern mathematics and it is difficult to overestimate its importance. I think it defines more unequivocally than anything else the inception of modern mathematics, and the system of mathematical analysis, which is its logical development, still constitutes the greatest technical advance in exact thinking.”
John von Neumann (1947)

But: Is the calculus adequate to study change of enterprise systems?

Typical assumptions about modeling the world

continuous change

continuum of objects (uncountable set) in total order*

Typical example

- set of real numbers
- typical total order on real numbers

* Let M be a set and < a binary relation on M. < is a partial order, iff < is irreflexive and transitive. < is a total order, iff < is a partial order and for all a, b element of M the following assumption holds: a < b or b < a or a = b.

Typical assumptions about modeling the world

continuous change	**versus**	**discrete change**
continuum of objects (uncountable set) in total order*		discrete set of objects (countable or even finite) in partial order*

Typical example

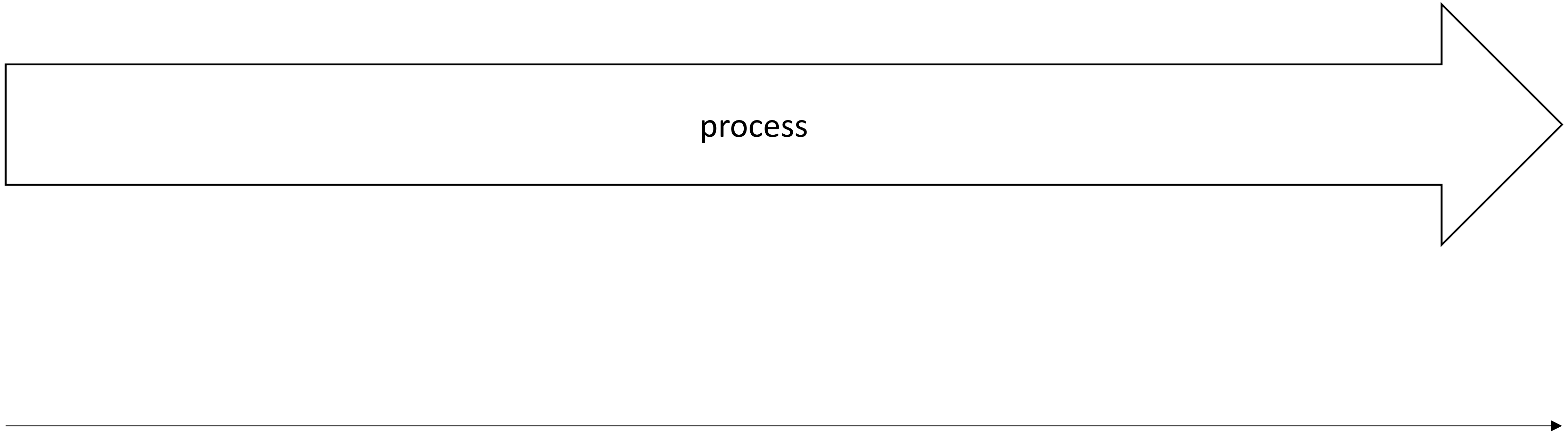
- set of real numbers
- typical total order on real numbers

Implications

- a total order is “just” a particular case of a partial order
- total order empirically discovered or intentionally designed

* Let M be a set and < a binary relation on M. < is a partial order, iff < is irreflexive and transitive. < is a total order, iff < is a partial order and for all a, b element of M the following assumption holds: a < b or b < a or a = b.

Process



continuum of **time** is typically assumed

But what is time in enterprise systems?

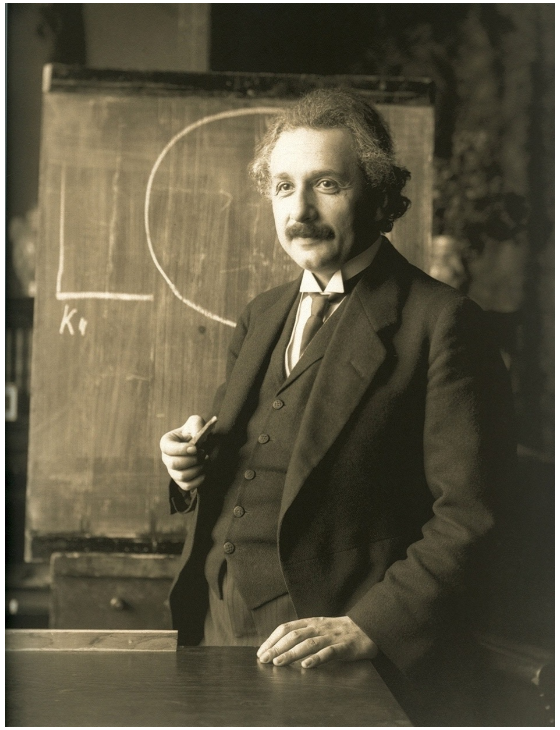
UNIVERSITÄT DES SAARLANDES

891

3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

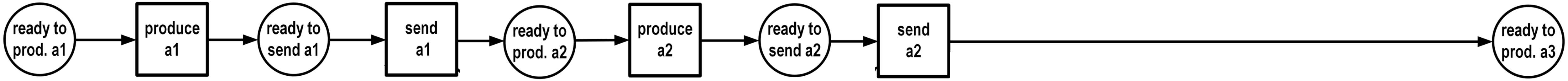
Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche



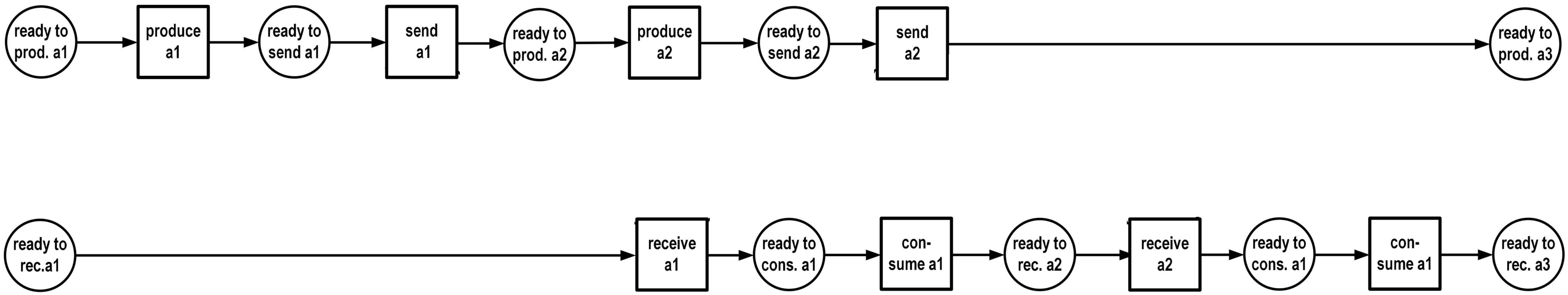
"We have to consider that all our judgments in which time plays a role are always judgments about simultaneous events. If, for example, I say: 'That train arrives here at 7 o'clock', this means something like: '**The pointing of the small hand of my watch** to 7 and the arrival of the train are ***simultaneous events***.'“

Einstein, 1905, p. 893, original in German, translation with deepL

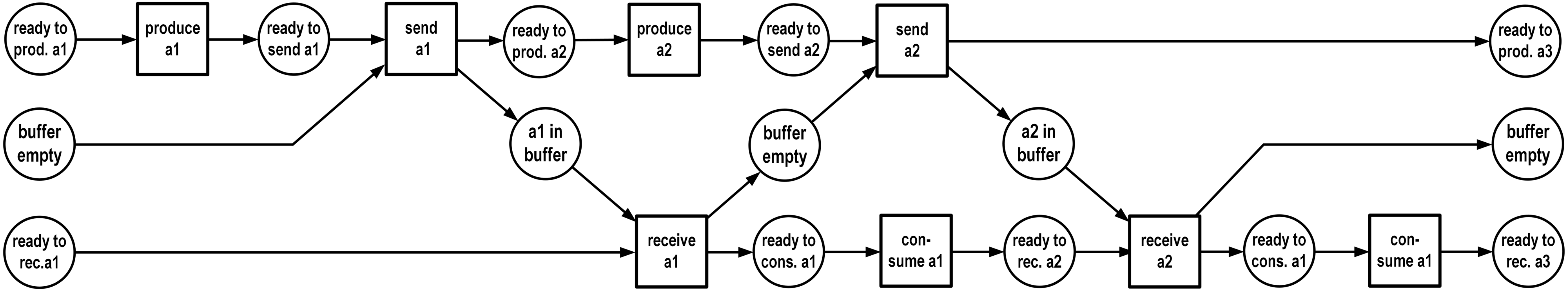
Maybe, events ("change") in enterprise systems are only partially ordered by a cause-effect-relation



Maybe, events ("change") in enterprise systems are only partially ordered by a cause-effect-relation



Maybe, events ("change") in enterprise systems are only partially ordered by a cause-effect-relation



Statics: data and real-life items

digital stamp with *matrix code*

Statics: data and real-life items

digital stamp with *matrix code*

structure S

sets
letters = {a, b, c}
stamps = {l, m, n, o}
matrix codes = {1, 2, 3}

functions

f: letters ⟶ stamps
f(a) = m, **f**(b) = n, **f**(c) = o

g: stamps ⟶ matrix codes
g(m) = 1, **g**(n) = 2, **g**(o) = 3

Statics: data and real-life items

digital stamp with *matrix code*

signature Σ

set symbols
letters
stamps
matrix codes

properties
- f is injective
- g is injective and partial

function symbols
f: letters ⟶ stamps
g: stamps ⟶ matrix codes

variables
x: letters

structure S

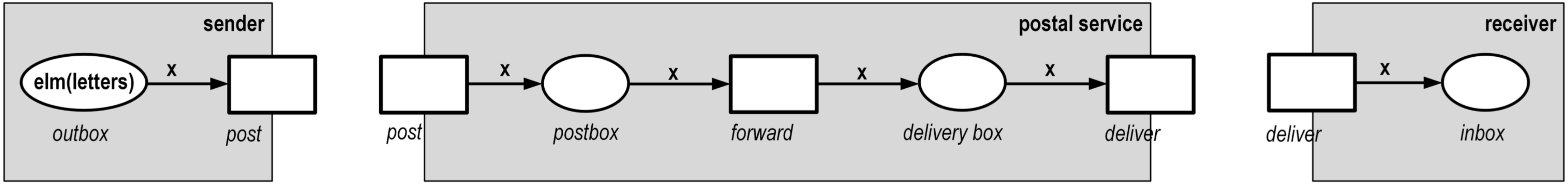
sets
letters = {a, b, c}
stamps = {l, m, n, o}
matrix codes = {1, 2, 3}

functions

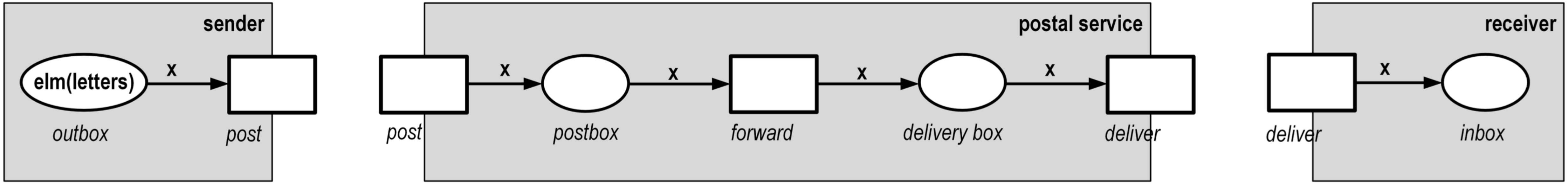
f: letters ⟶ stamps
f(a) = m, **f**(b) = n, **f**(c) = o

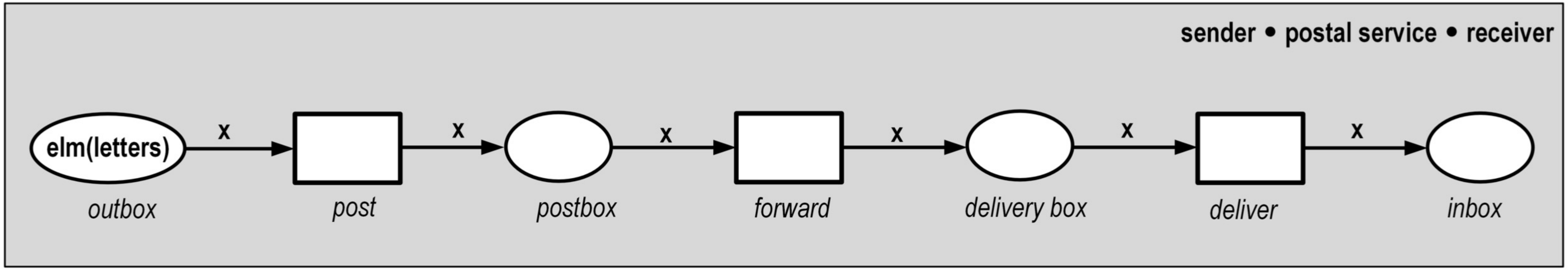
g: stamps ⟶ matrix codes
g(m) = 1, **g**(n) = 2, **g**(o) = 3

Architecture: composition matters



Architecture: composition matters





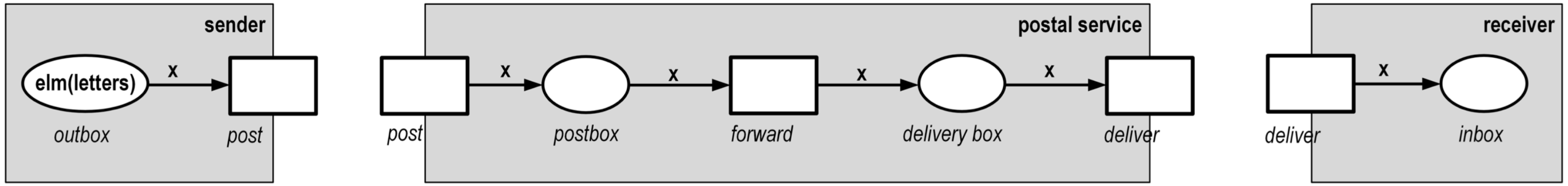
Completing the example: stamp with matrix code

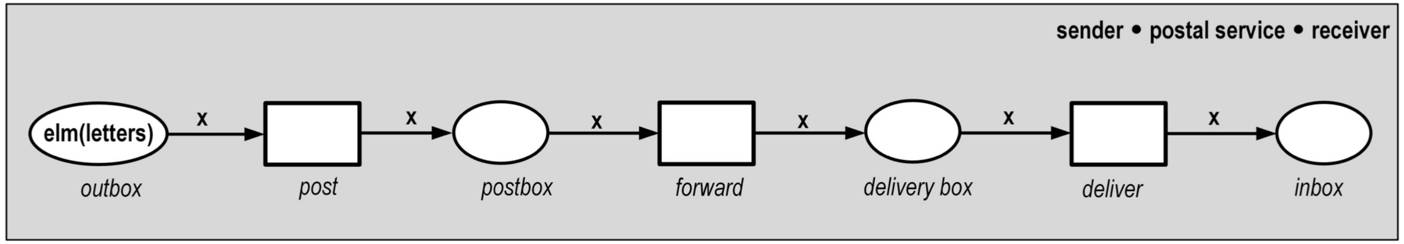
set symbols
letters
stamps
matrix codes

properties
- f is injective
- g is injective and partial

function symbols
f: letters ⟶ stamps
g: stamps ⟶ matrix codes

variables
x: letters





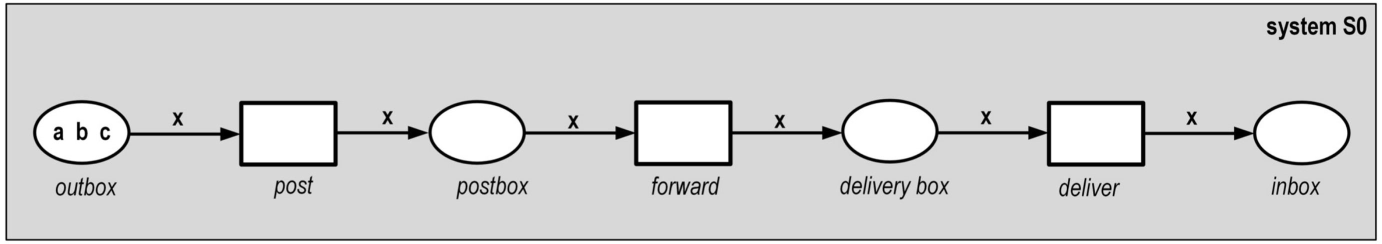
---

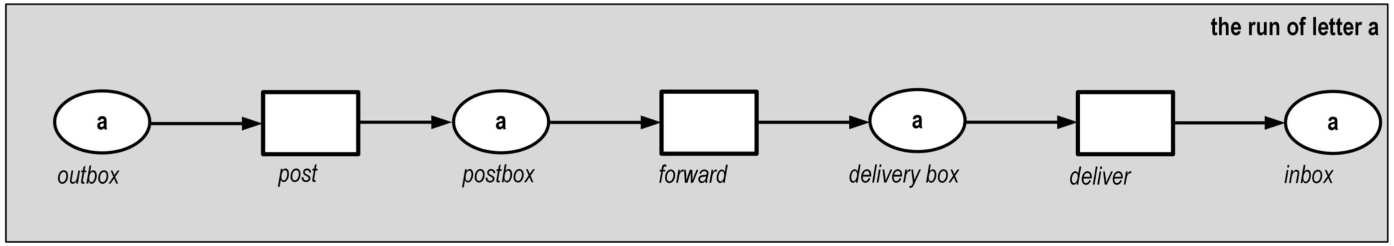
sets
letters = {a, b, c}
stamps = {l, m, n, o}
matrix codes = {1, 2, 3}

functions

f: letters ⟶ stamps
f(a) = m, **f**(b) = n, **f**(c) = o

g: stamps ⟶ matrix codes
g(m) = 1, **g**(n) = 2, **g**(o) = 3





Completing the example: stamp with matrix code

signature

set symbols
letters
stamps
matrix codes

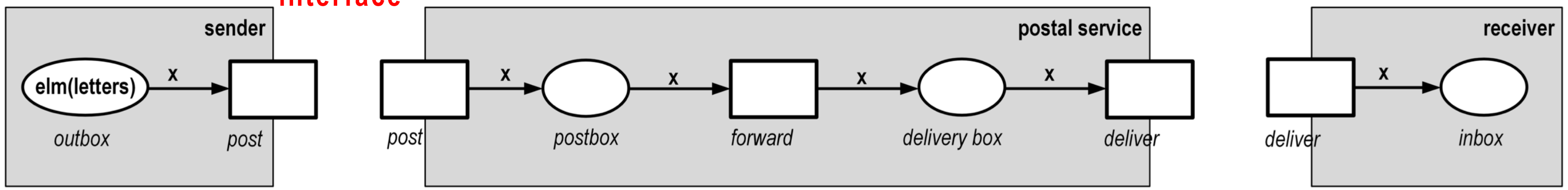
properties
- f is injective
- g is injective and partial

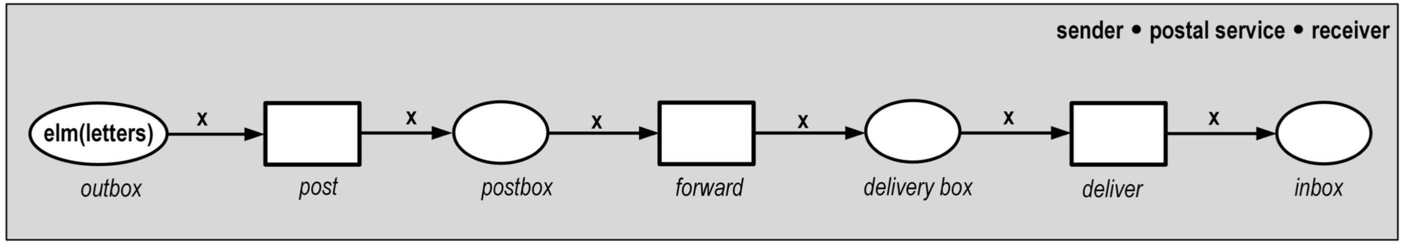
function symbols
f: letters ⟶ stamps
g: stamps ⟶ matrix codes

variables
x: letters

three modules

interface





composed module

causal order

schema

---

instatiation

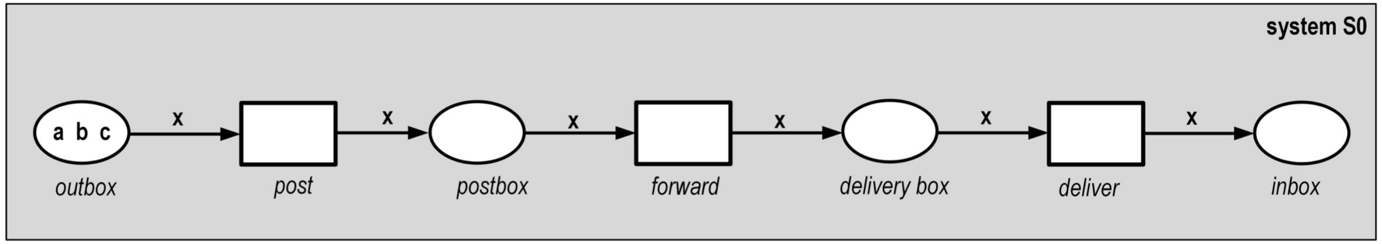
structure

sets
letters = {a, b, c}
stamps = {l, m, n, o}
matrix codes = {1, 2, 3}

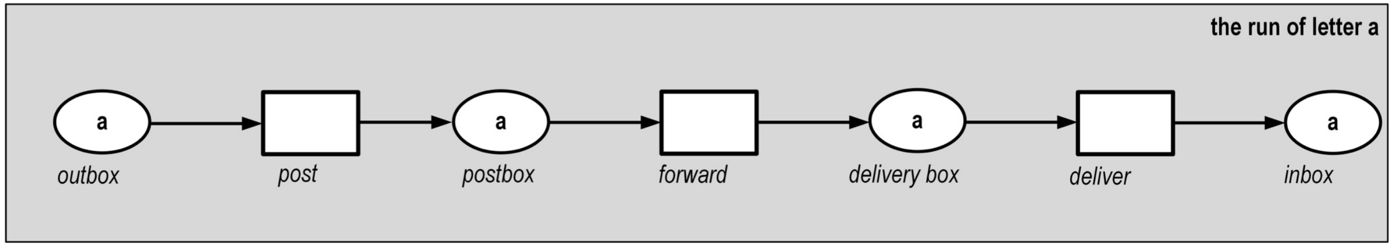
functions

f: letters ⟶ stamps
f(a) = m, **f**(b) = n, **f**(c) = o

g: stamps ⟶ matrix codes
g(m) = 1, **g**(n) = 2, **g**(o) = 3



system



run

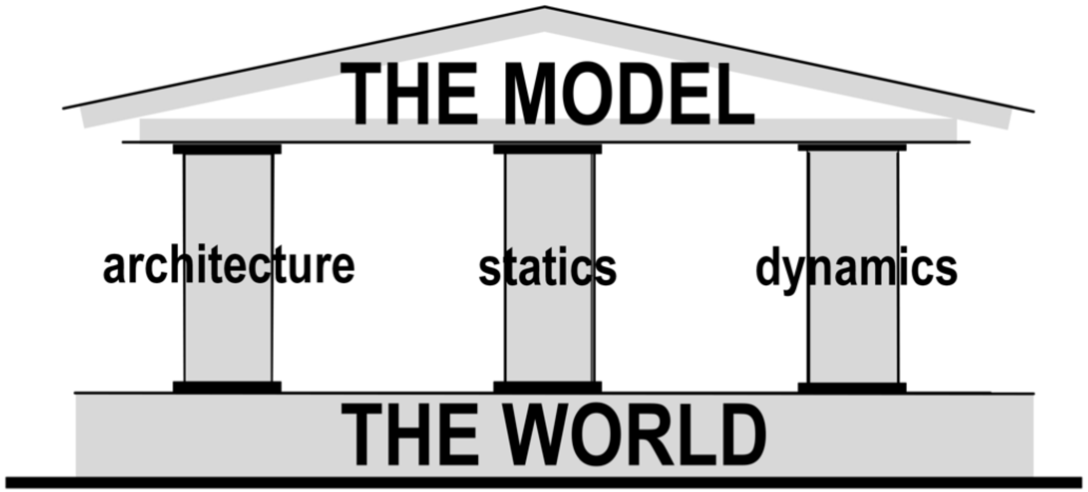
How to understand the world (summary)?

A comprehensive conceptual model of a computer-integrated system

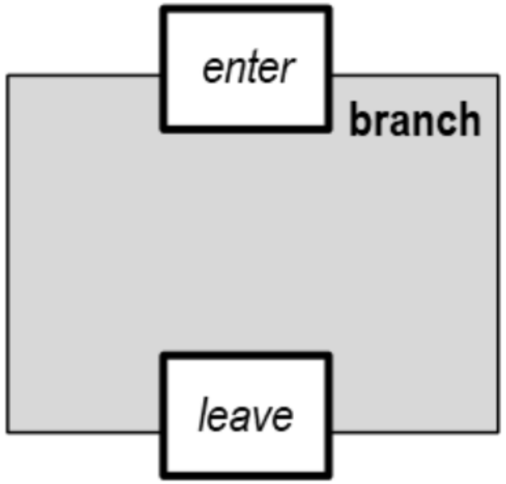
(1) is structured	**architecture**	**composition matters!**
(2) includes data *and* real-life items	**statics**	**objects matter!**
(3) is locally updated.	**dynamics**	**causality matters!**

Modeling in computer science is about changing the perspective:

- classical *theoretical computer science* and *software engineering* start with computers,
- *modeling* starts with the considered system and the problem.

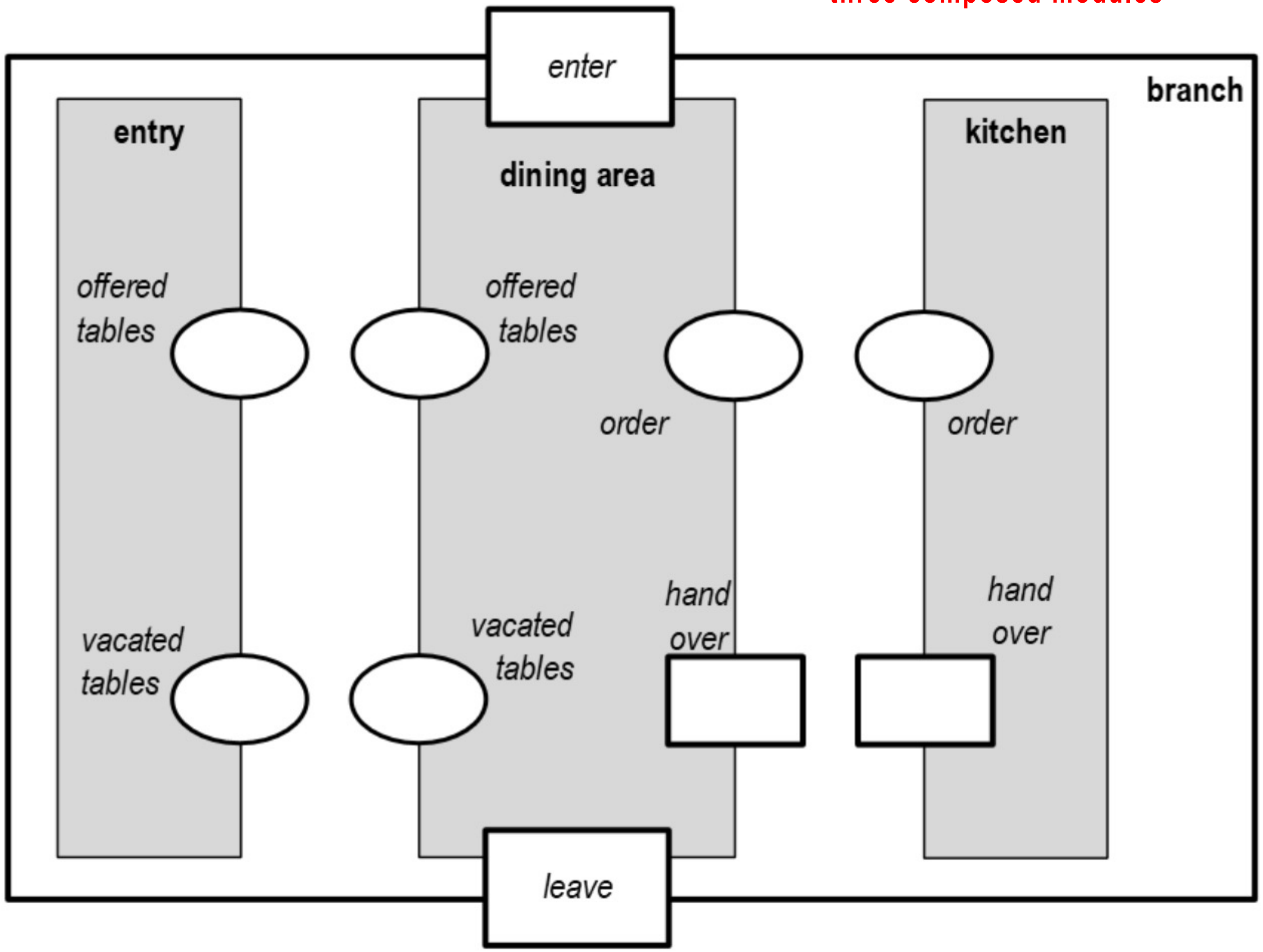


Restaurant (architecture)



abstract module

three composed modules



Restaurant (statics)

signature

set symbols
C: *clients*
T: *tables*
M: *order items (called menu)*
D: *meal items*

derived symbols
P: *subsets of* **M**, called *orders*
Q: *subsets of* **D**, called *meals*

function symbols
f: **D** ⟶ **M**
g: **Q** ⟶ **P**

properties
for **A** ⊆ **D**:
g(**A**) = {**f**(**a**) | **a** ∈ **A**}

variables
c: **C**
t: **T**
X: **P**
y: **D**
Y: **Q**

schema

structure

sets
C: all persons with an id card
T: {t1, t2, t3, t4}
M: {<u>rice</u>, <u>meat</u>, <u>salad</u>}
D: {rice, rice, meat, salad}

derived symbols
P: {{<u>rice</u>, <u>meat</u>}, {<u>rice</u>, <u>salad</u>}}
Q: {{rice, meat}, {rice, salad}}

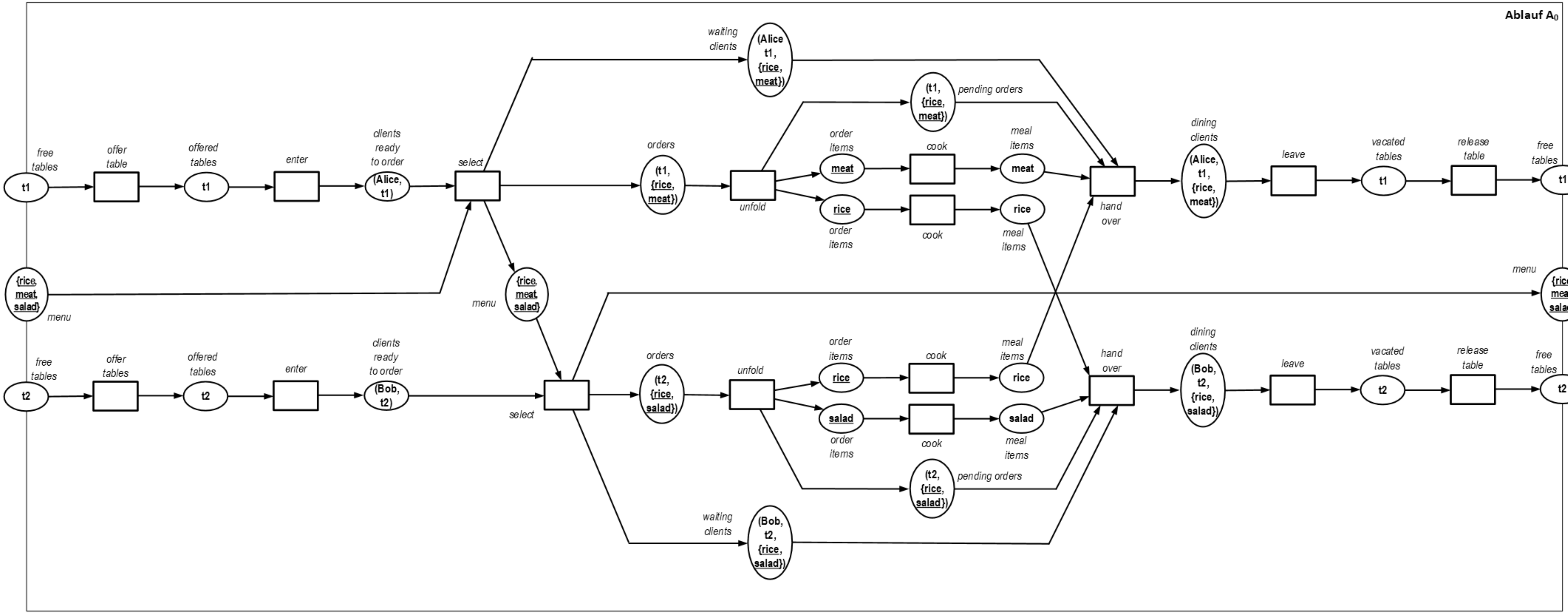
functions
f: **D** ⟶ **M**
f(rice) = <u>rice</u>
f(meat) = <u>meat</u>
f(salad) = <u>salad</u>

g: **P** ⟶ **Q**
g({<u>rice</u>, <u>meat</u>}) = {rice, meat}
g({<u>rice</u>, <u>salad</u>}) = {rice, salad}

instantiation

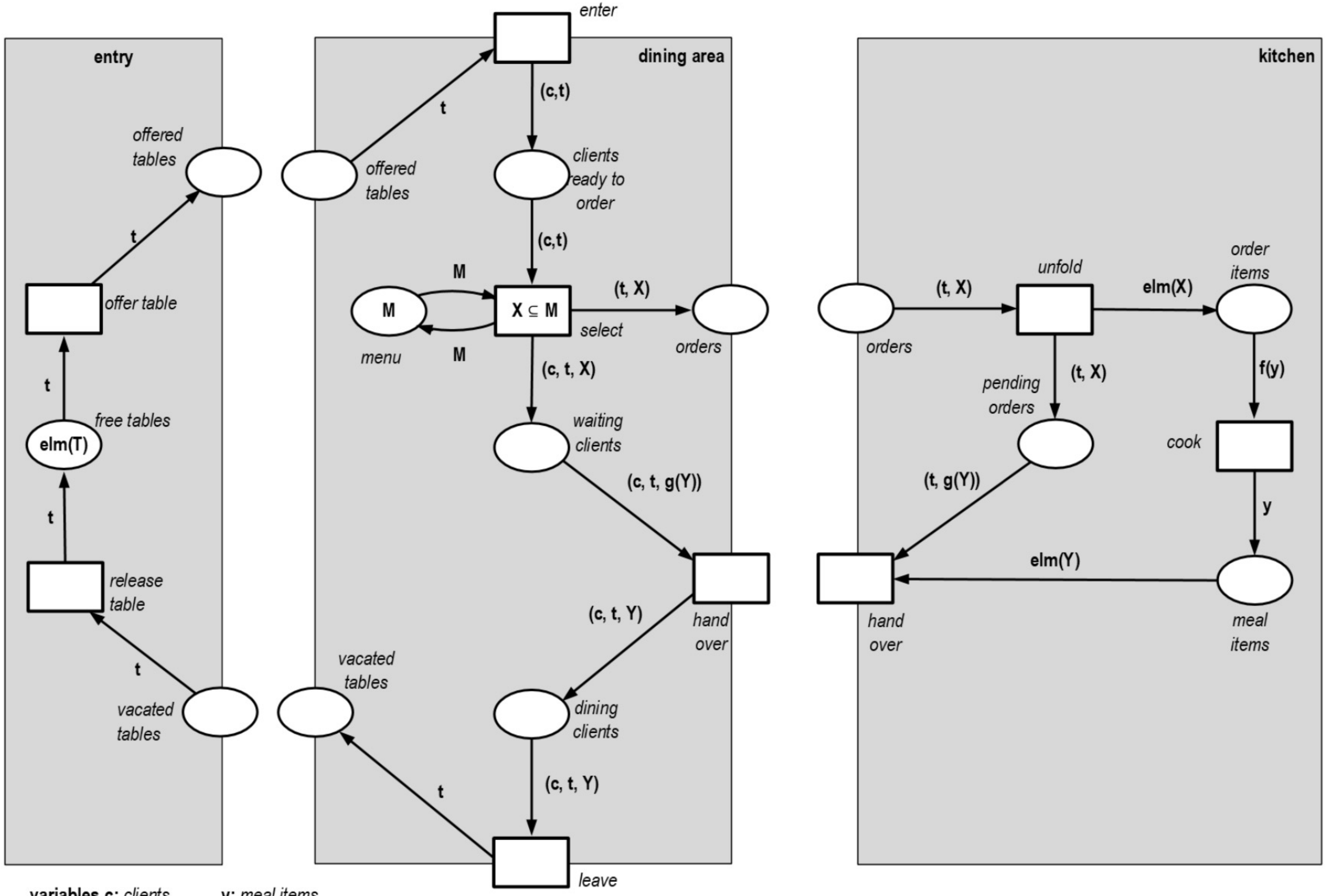
Restaurant (dynamics)

instantiation, a run



Restaurant (dynamics)

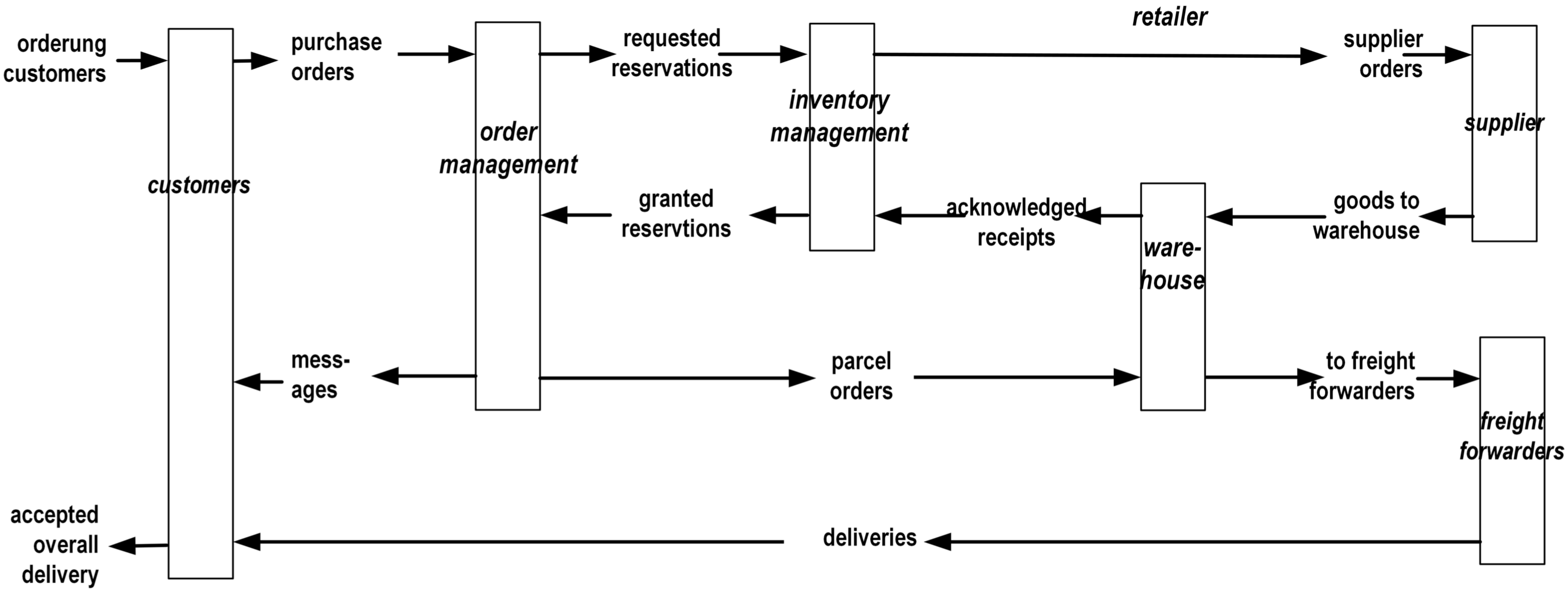
schema



variables c: *clients* **y:** *meal items*
t: *tables* **Y:** *meals*
X: *orders*

three modules

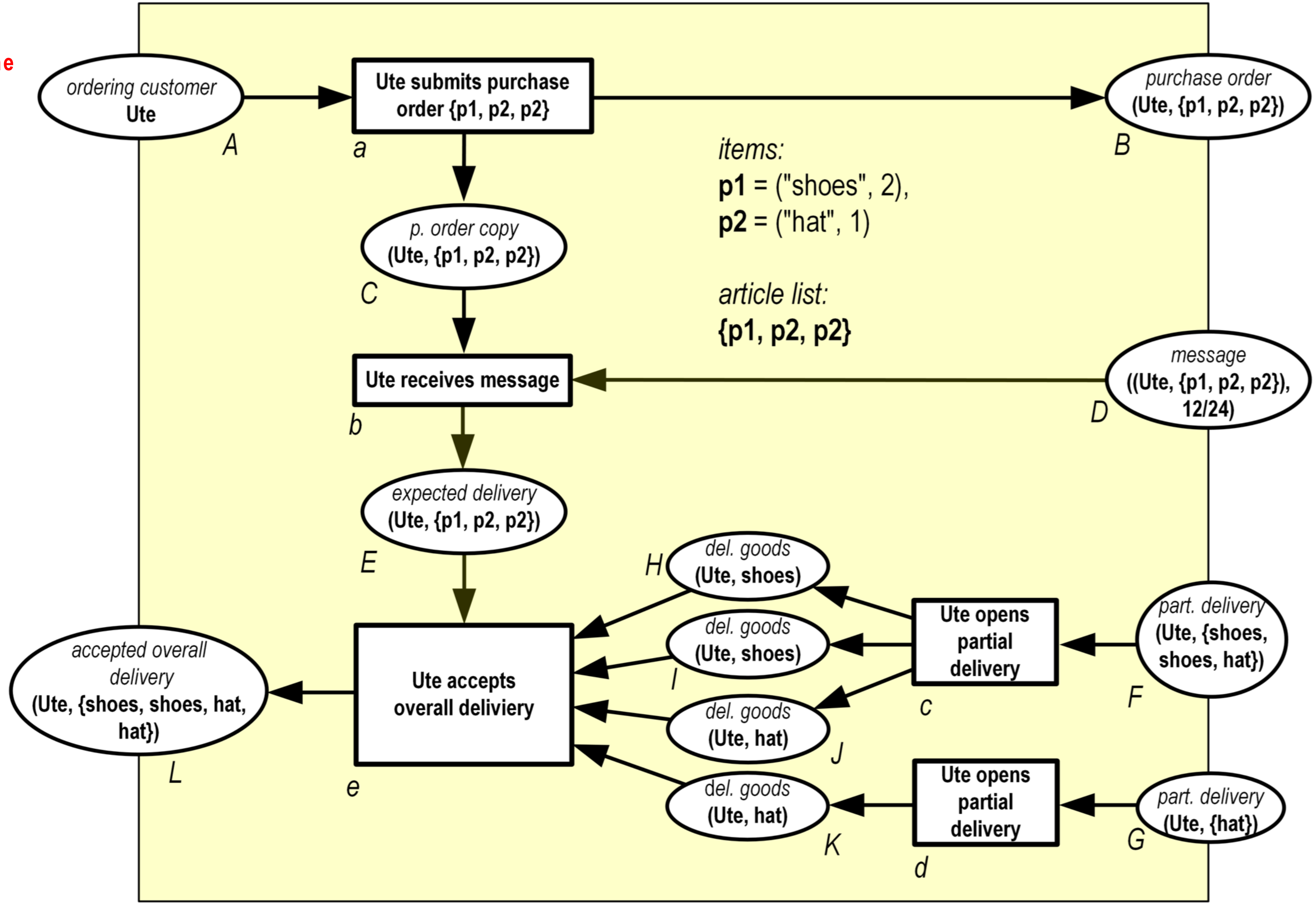
Retailer (architecture)



six composed modules

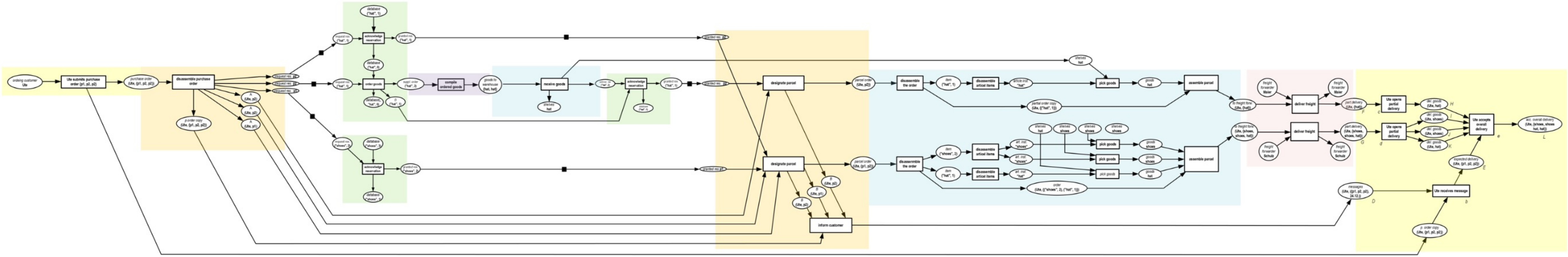
Retailer (dynamics)

one instantiation of the customer module



Retailer (dynamics)

instantiation,
a run



Retailer (statics)

ground sorts
KN *customers*
AR *articles*
WA *goods*
TE *dates*
SP *freight forwarders*

derived sorts
AP = **AR** × ℕ *items*
AL = ***M*(AP)** *article lists*
AM = ***M*(AR)** *sets of articles*
WM = ***M*(WA)** *sets of goods*

constant symbols
p1, p2: AP *ordered article positions*
B: P(KN) *ordering customers*
G : AL *initially listed articles*
H : WM *initially available goods*
R : P(SP) *available freight forwarders*

signature

function symbols
f : WA ⟶ AR
f : WM ⟶ AM
(_'): AP ⟶ AM
(_'): AL ⟶ AM

variables
k: KN
x: AR
X,Y: AL
Z: WM
t: TE
w: WA
s: SP
m, n, p: ℕ

properties
(a,n)' = n[a] for (a,n)∈ **AP**
[p1, … , pn]' = p1' + … + pn' for
[p1, … , pn] ∈ **AL**

G' = f(H)

schema

structure

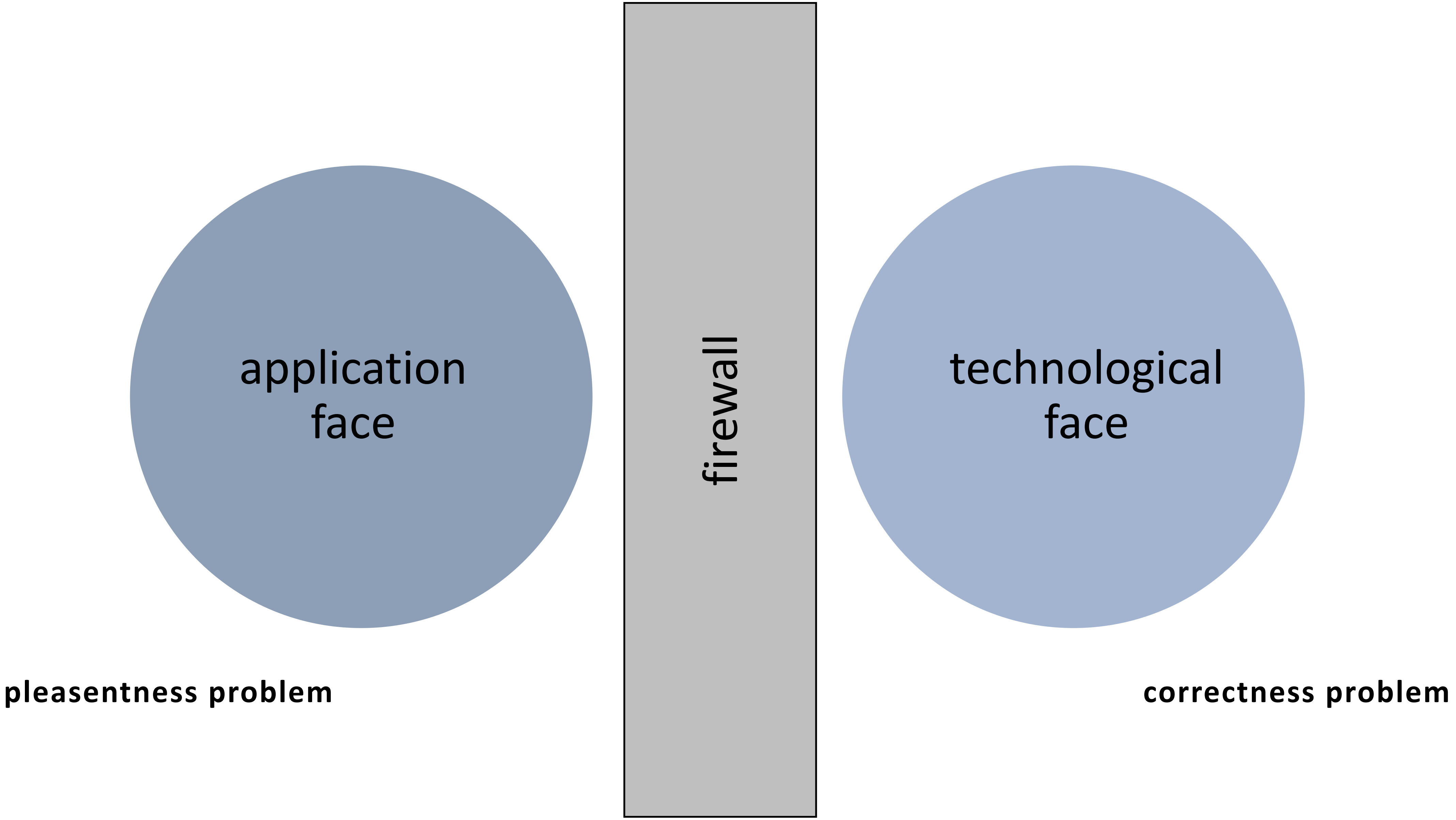
ground sorts
KN = {Ute, Max} *customers*
AR = {"shoes", "hat", "pants"} *articles*
WA = {shoes, hat, pants} *goods*
TE = {12/23, 12/24} *dates*
SP = {Maier, Müller, Schulz} *freight forwarders*

instantiation

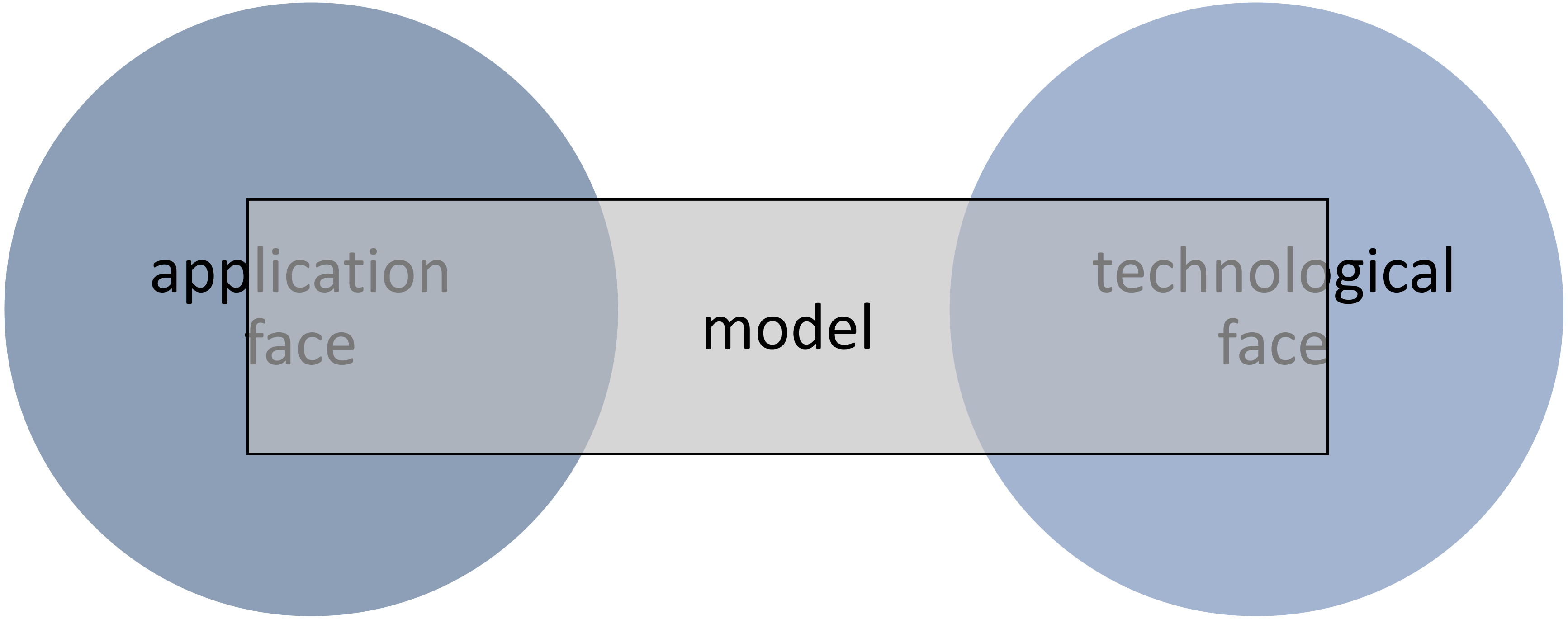
Agenda

1. Preliminary Remarks
2. Future of Enterprise Modeling
3. Implications and Conclusions

Two faces of computer science and Dijskra‘s firewall



Two faces of computer science and next-generation modeling



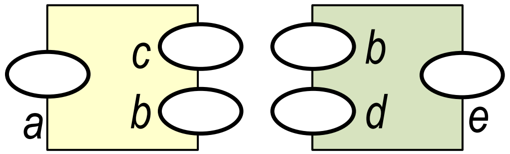
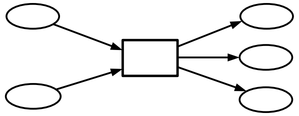
pleasentness problem

“bridge”

- freely-selectable abstraction level
- relevant real- and imagined world (architecture, statics, dynamics)

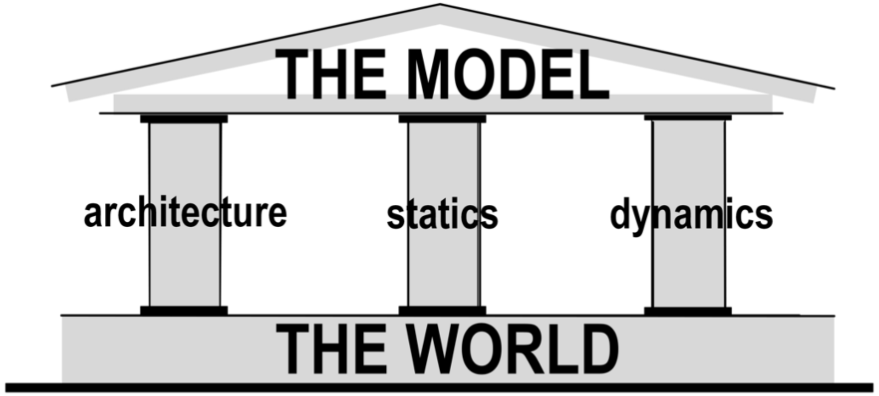
correctness problem

Summing up: What is next generation enterprise modeling all about?

classical computer science	*… yes, but …*	*… adjusted*	*… such as*	*… technically*
modules and composition: merge “equal” interface elements	yes, however not *one* interface	but two!		composition calculus
statics (data, items): symbolic representation	yes, however not with symbol *chains* (“strings”)	but with terms over a signature!	**f(x, g(a,y))**	predicate logic, algebraic specification
dynamics: steps	yes, however, not *global* states and steps	but local ones!		Petri nets

classical computer science

- jump in the right direction
- but fall short



Don‘t hesitate!

Join the HERAKLIT.org research program and development project

Thanks for your attention! Questions?

Contact
Professor Dr. Peter Fettke
Universität des Saarlandes und
Deutsches Forschungszentrum für Künstliche Intelligenz (DFKI)
Campus D 3 2
66123 Saarbrücken, Germany
peter.fettke@dfki.de
Telefon: +49 681 85775-5142, Fax: -3696