Universität Hamburg
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Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics
Research Group on Scene Analysis and Visualisation (SAV)

Graphical Languages for Functional Reactive Modeling based on Petri nets

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Outline

- Related works: functional approaches to modeling
- The Reference Net formalism
- Functional reactive modeling with Reference Nets
- Functional components
- RMT approach: developing domain-specific modeling tools
- Home automation example

Related Works

- Functional block diagrams
  - Modelica (Tiller, 2001)
  - Matlab Simulink (Xue and Chen, 2013)
- Graphical functional reactive programming
  - Akka streams, Apache Spark (Davis, 2019)
- Metamodeling environments with execution semantics
  - GEMOC Studio (Combemale et al., 2017)
- Functional languages and Petri nets
  - Coloured Petri nets (Jensen and Kristensen, 2009)
  - Curry-Coloured Petri nets (Simon et al., 2019)

Goals / Approach

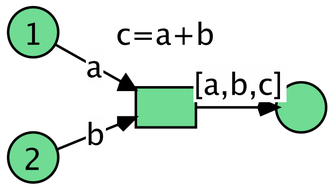
Goal: unify the following characteristics (to a unique approach)

- Graphical languages → easy to follow
- Meta modeling → quick results for building tools
- Operational semantics → can execute in simulation environment
- Functional decomposition → clear notion of components, referential transparency
- Reactive programming → communicate with environment

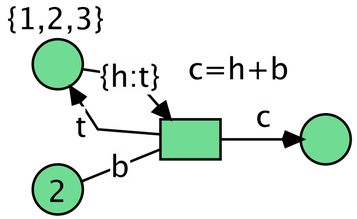
Approach

- Develop Reference net components that capture functional properties for the specification of domain specific modeling languages using operational semantics
- Higher order functions: nets-within-nets paradigm of Reference Nets
- Model driven: generate modeling tools

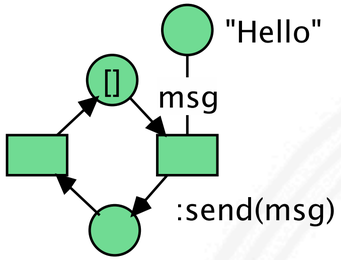
Reference Nets



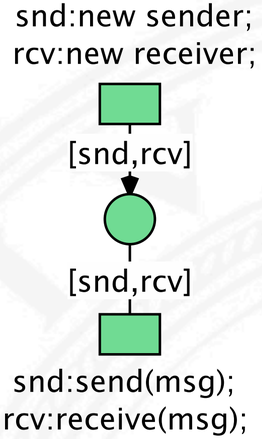
Tuples



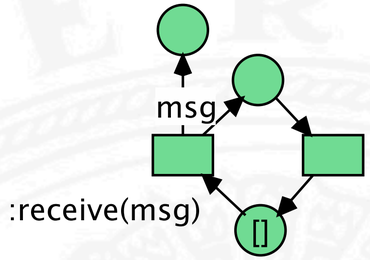
Lists



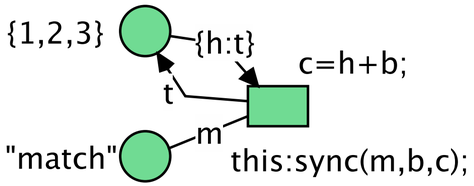
Sender

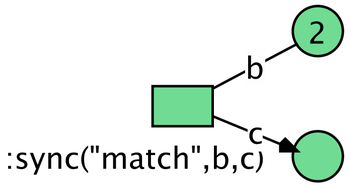


System



Receiver





Synchronous Channels

Functional Reactive Systems

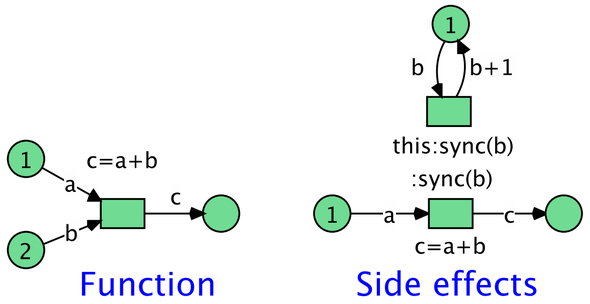
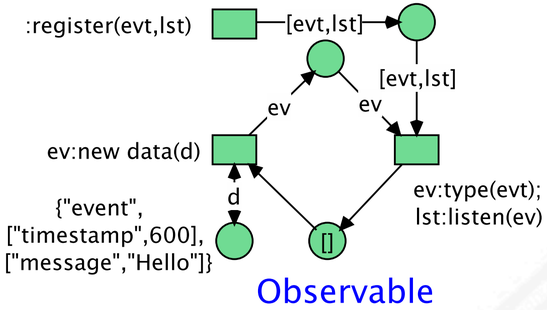


Figure 4: A functional perspective on Reference Nets



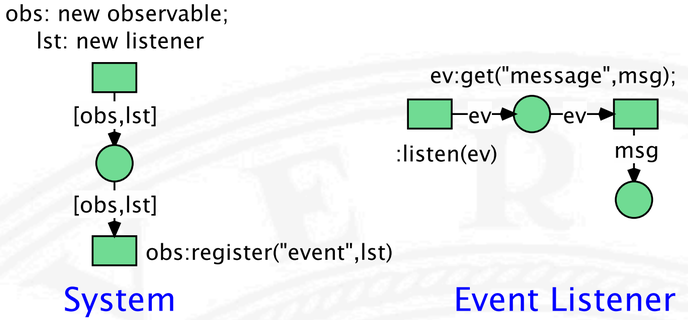


Figure 6: A reactive system

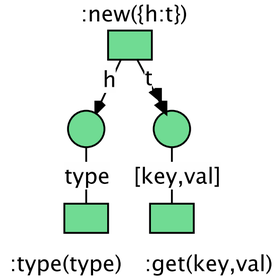
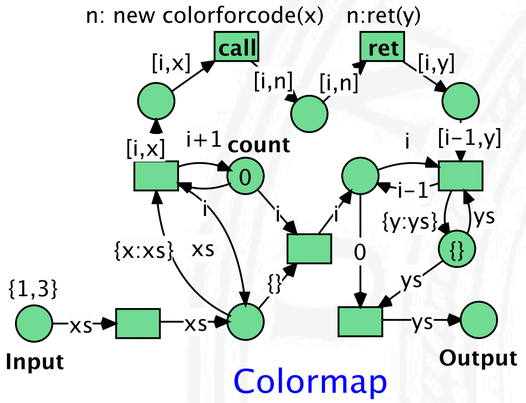


Figure 5: An immutable named key-value pair data structure



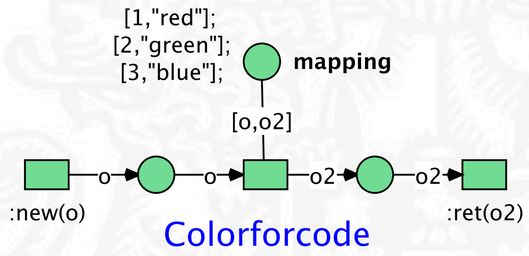
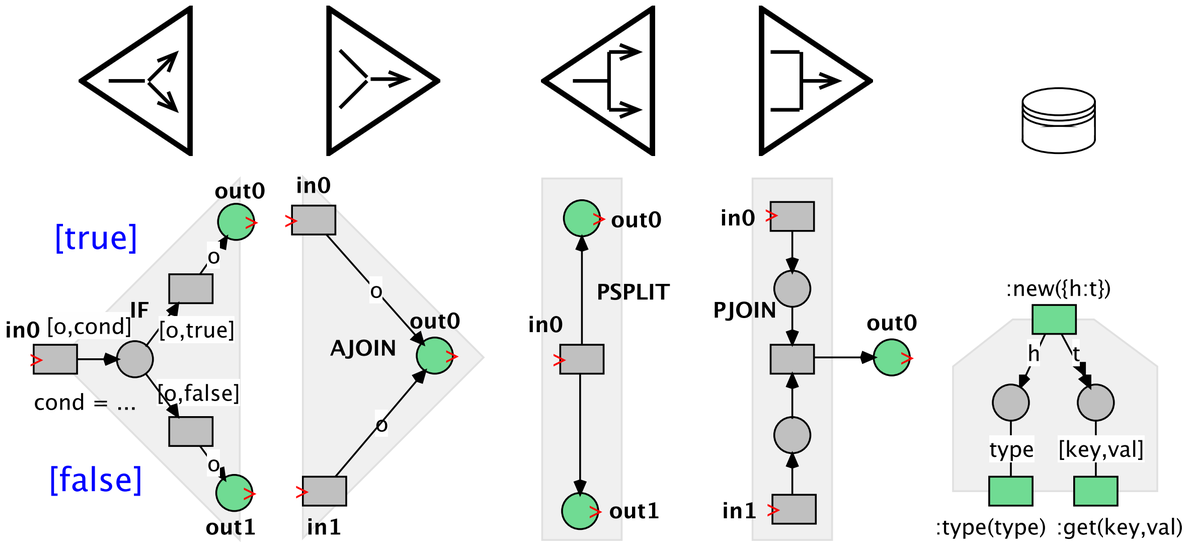


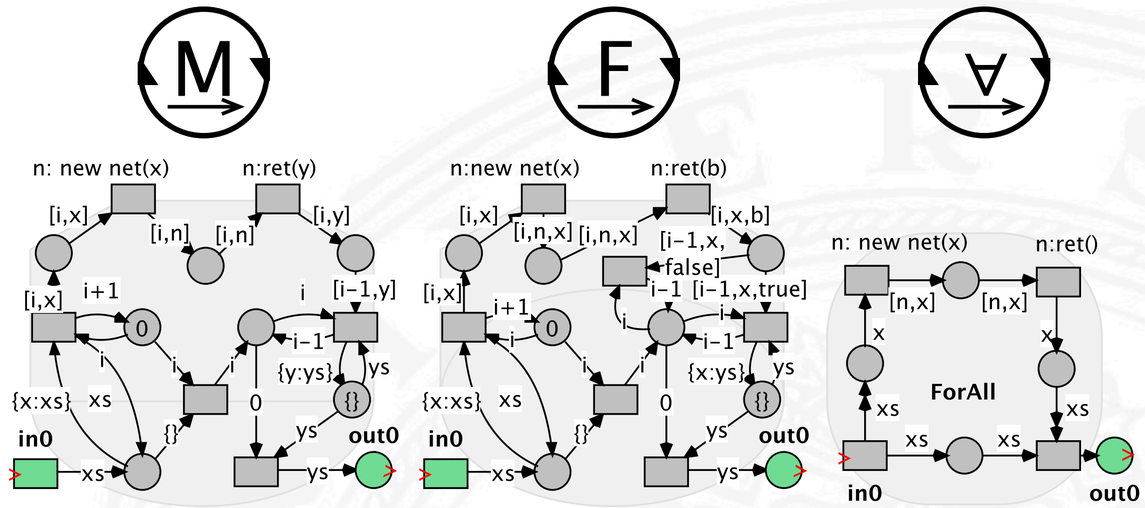
Figure 7: Higher-order functions

Semantic Components

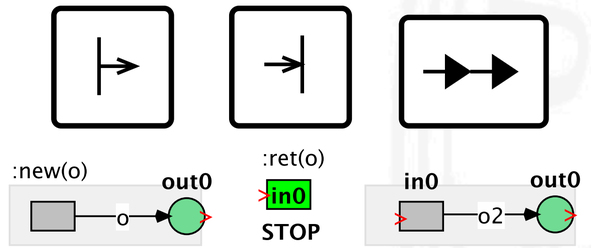
XOR-Split XOR-Merge Parallel Split Parallel Join Data



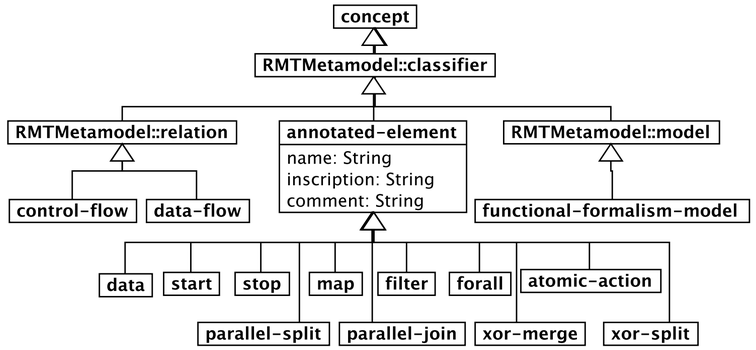
Map Filter Forall



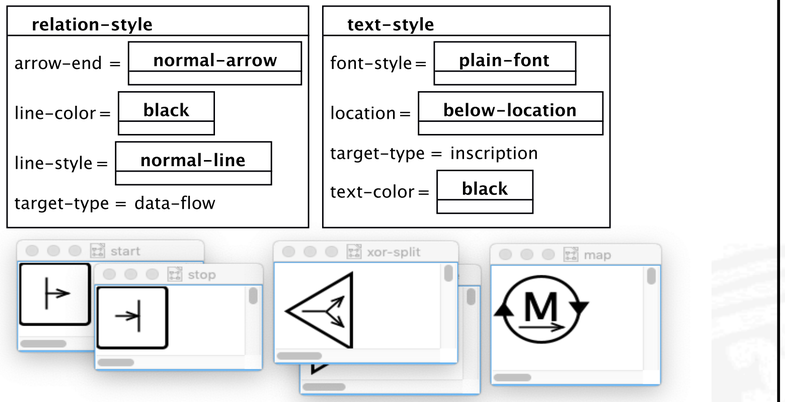
Start Stop Action



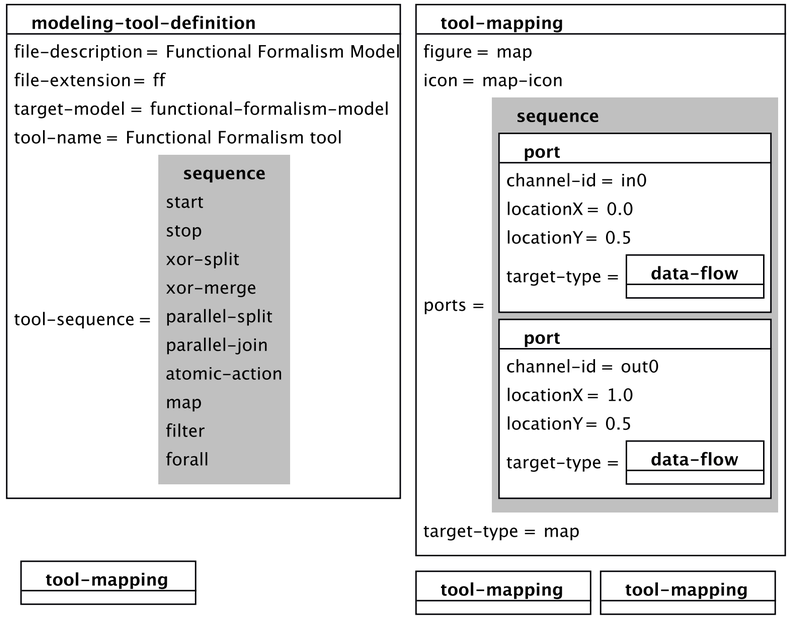
Abstract Syntax

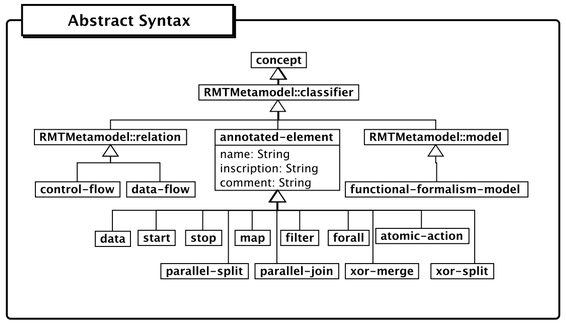


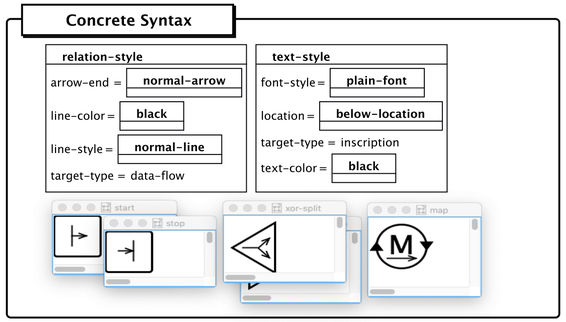
Concrete Syntax

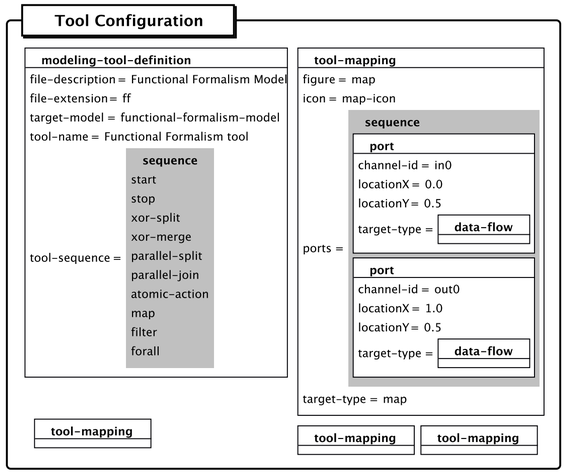


Tool Configuration



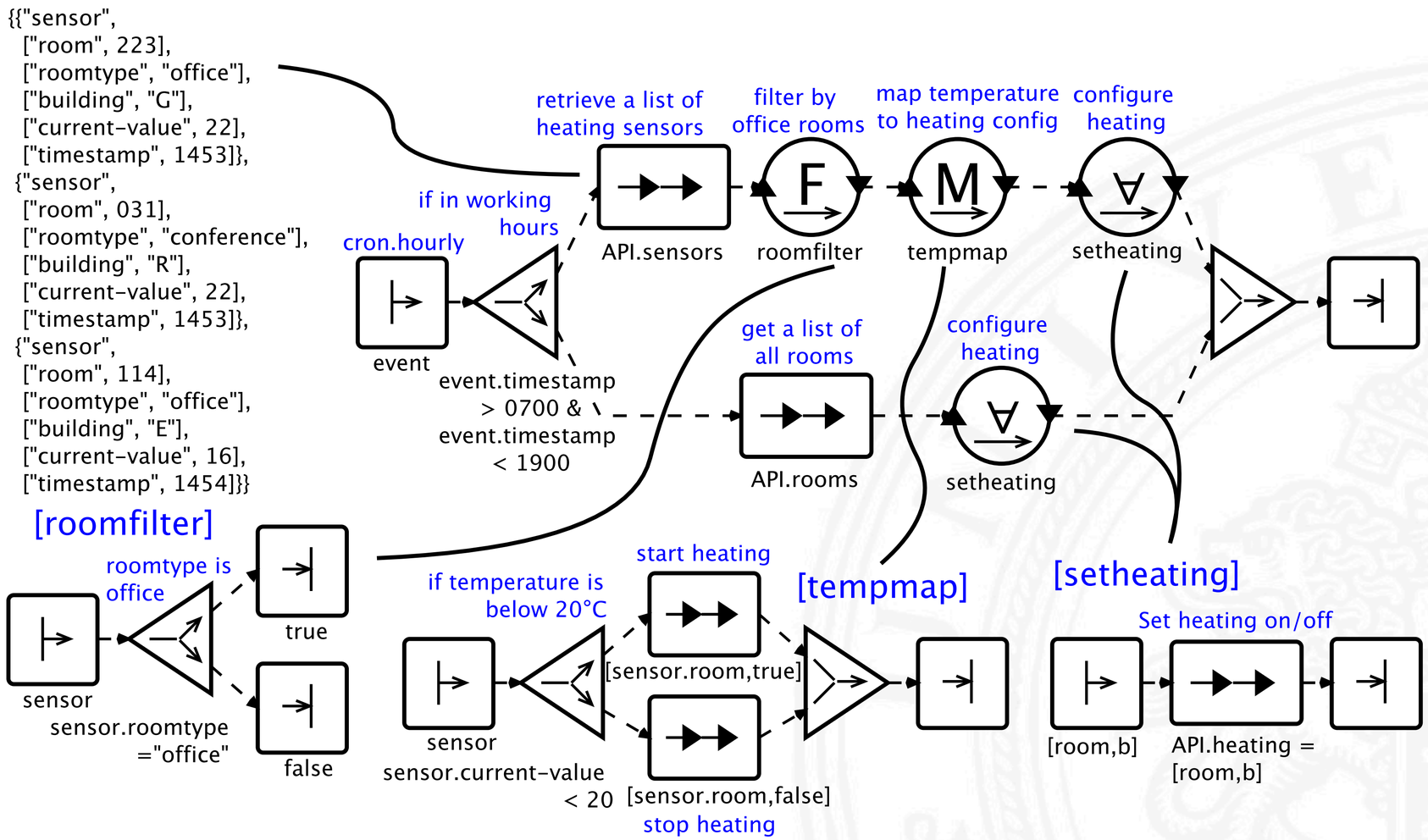

Abstract Syntax
concept
RMTMetamodel::classifier
RMTMetamodel::relation
annotated-element
name: String
inscription: String
comment: String
RMTMetamodel::model
control-flow
data-flow
functional-formalism-model
data
start
stop
map
filter
forall
atomic-action
parallel-split
parallel-join
xor-merge
xor-split

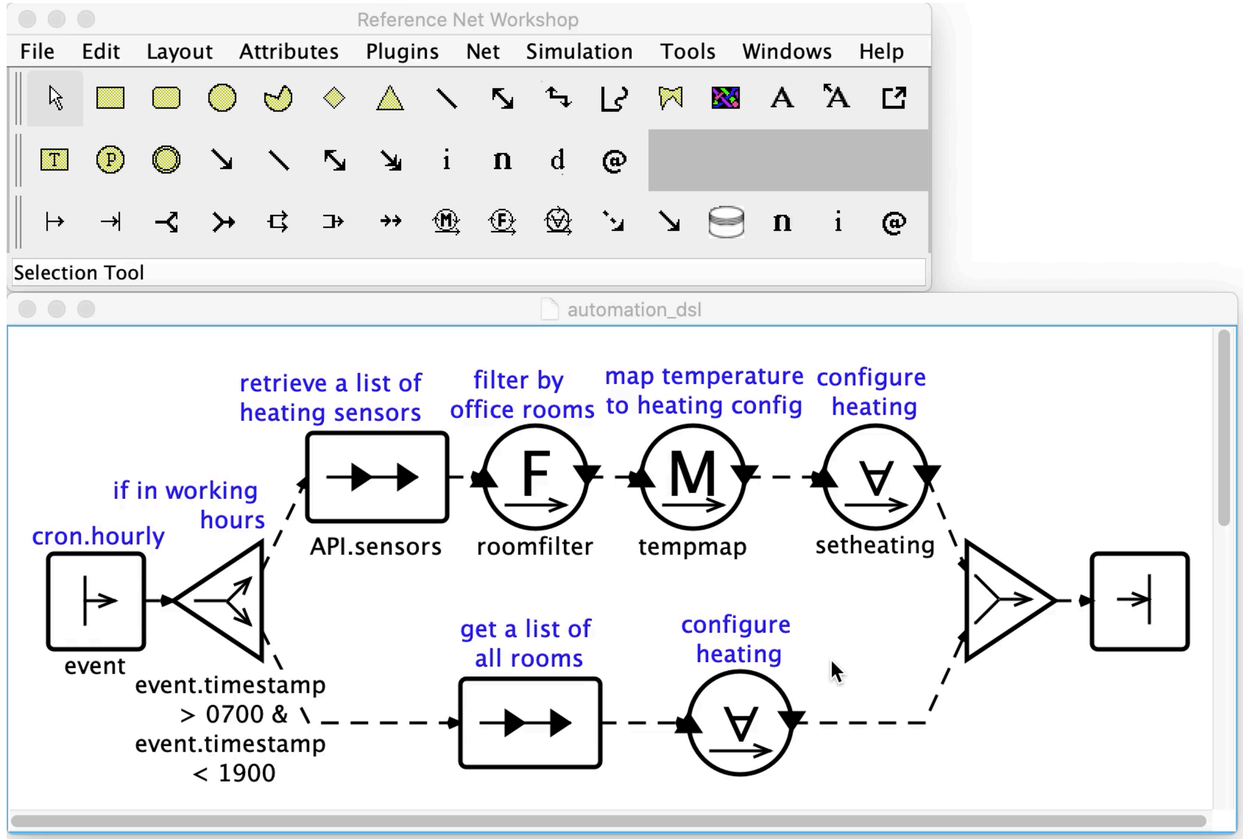

Concrete Syntax
relation-style
arrow-end = normal-arrow
line-color = black
line-style = normal-line
target-type = data-flow
text-style
font-style = plain-font
location = below-location
target-type = inscription
text-color = black
start
stop
xor-split
map
M

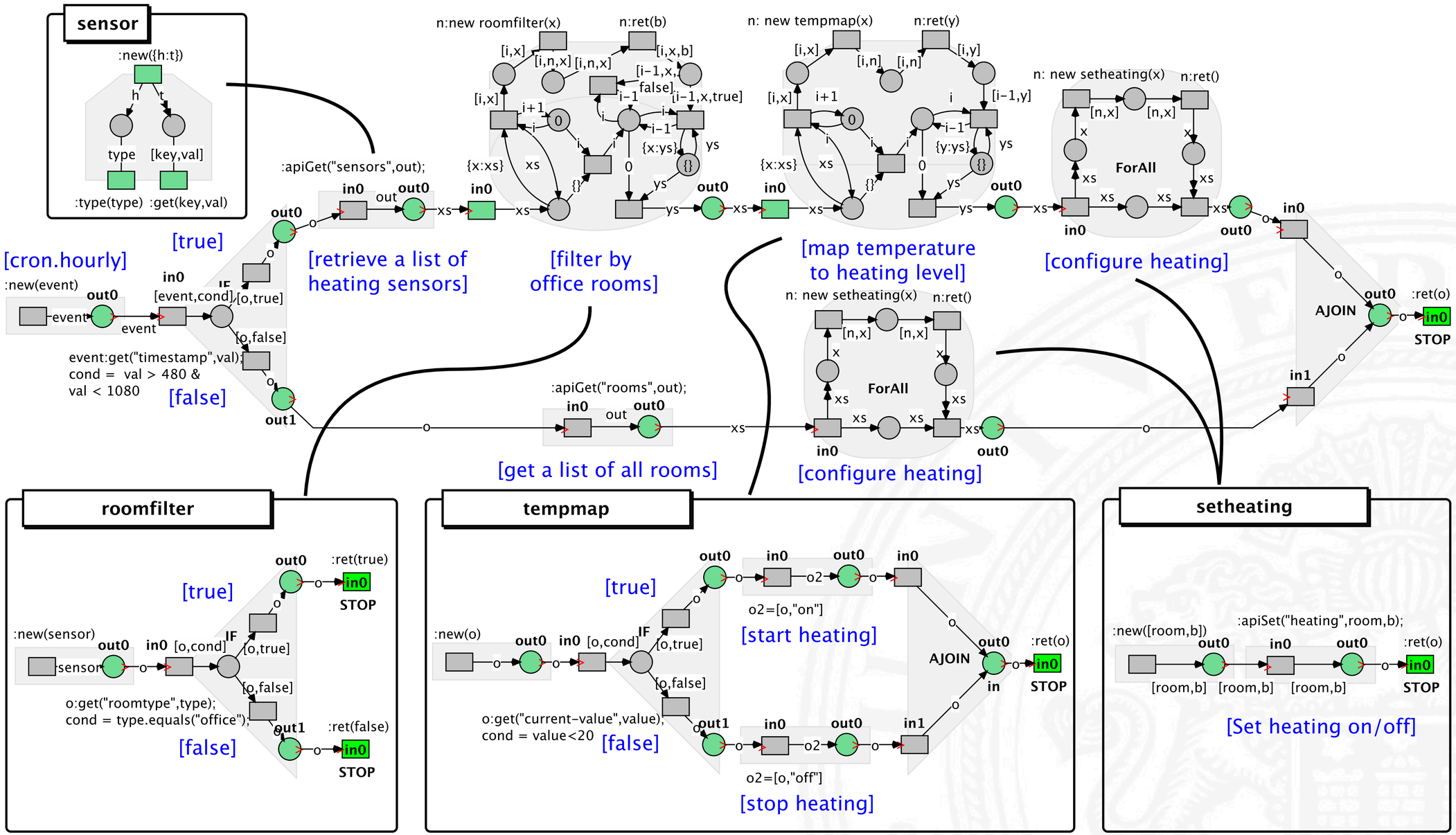

Tool Configuration
modeling-tool-definition
file-description = Functional Formalism Model
file-extension = ff
target-model = functional-formalism-model
tool-name = Functional Formalism tool
tool-sequence =
sequence
start
stop
xor-split
xor-merge
parallel-split
parallel-join
atomic-action
map
filter
forall
tool-mapping
figure = map
icon = map-icon
ports =
sequence
port
channel-id = in0
locationX = 0.0
locationY = 0.5
target-type = data-flow
port
channel-id = out0
locationX = 1.0
locationY = 0.5
target-type = data-flow
target-type = map
tool-mapping
tool-mapping
tool-mapping


FunctionalFormalism — -zsh — 73×17
$ ./testing/start.sh -r

Heating Control DSML




Reference Net Workshop
File Edit Layout Attributes Plugins Net Simulation Tools Windows Help
Selection Tool
automation_dsl
retrieve a list of heating sensors
filter by office rooms
map temperature to heating config
configure heating
if in working hours
cron.hourly
API.sensors
roomfilter
tempmap
setheating
event
event.timestamp > 0700 & \ event.timestamp < 1900
get a list of all rooms
configure heating


sensor
:new({h:t})
h
t
type
[key,val]
:type(type)
:get(key,val)
[true]
[cron.hourly]
:new(event)
out0
event
in0
[event,cond]
IF
[o,true]
[o,false]
event:get("timestamp",val);
cond = val > 480 &
val < 1080
[false]
out1
:apiGet("sensors",out);
in0
out
out0
[retrieve a list of heating sensors]
n:new roomfilter(x)
n:ret(b)
[filter by office rooms]
n: new tempmap(x)
n:ret(y)
[map temperature to heating level]
n: new setheating(x)
n:ret()
ForAll
[configure heating]
:apiGet("rooms",out);
[get a list of all rooms]
n: new setheating(x)
n:ret()
ForAll
[configure heating]
AJOIN
in1
:ret(o)
STOP
roomfilter
:new(sensor)
:sensor
o:get("roomtype",type);
cond = type.equals("office");
:ret(true)
:ret(false)
tempmap
:new(o)
o:get("current-value",value);
cond = value<20
o2
o2=[o,"on"]
[start heating]
o2=[o,"off"]
[stop heating]
setheating
:new([room,b])
:apiSet("heating",room,b);
[room,b]
[Set heating on/off]

Conclusion

Results

- Employ Reference Nets to model functional reactive systems and complex data structures
- RMT approach: development of DSML with functional component-based semantics
- Home automation DSML to control a heating system

Future work

- Formal analysis of DSML with functional semantics
- Petri net concepts for real higher-order functions

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