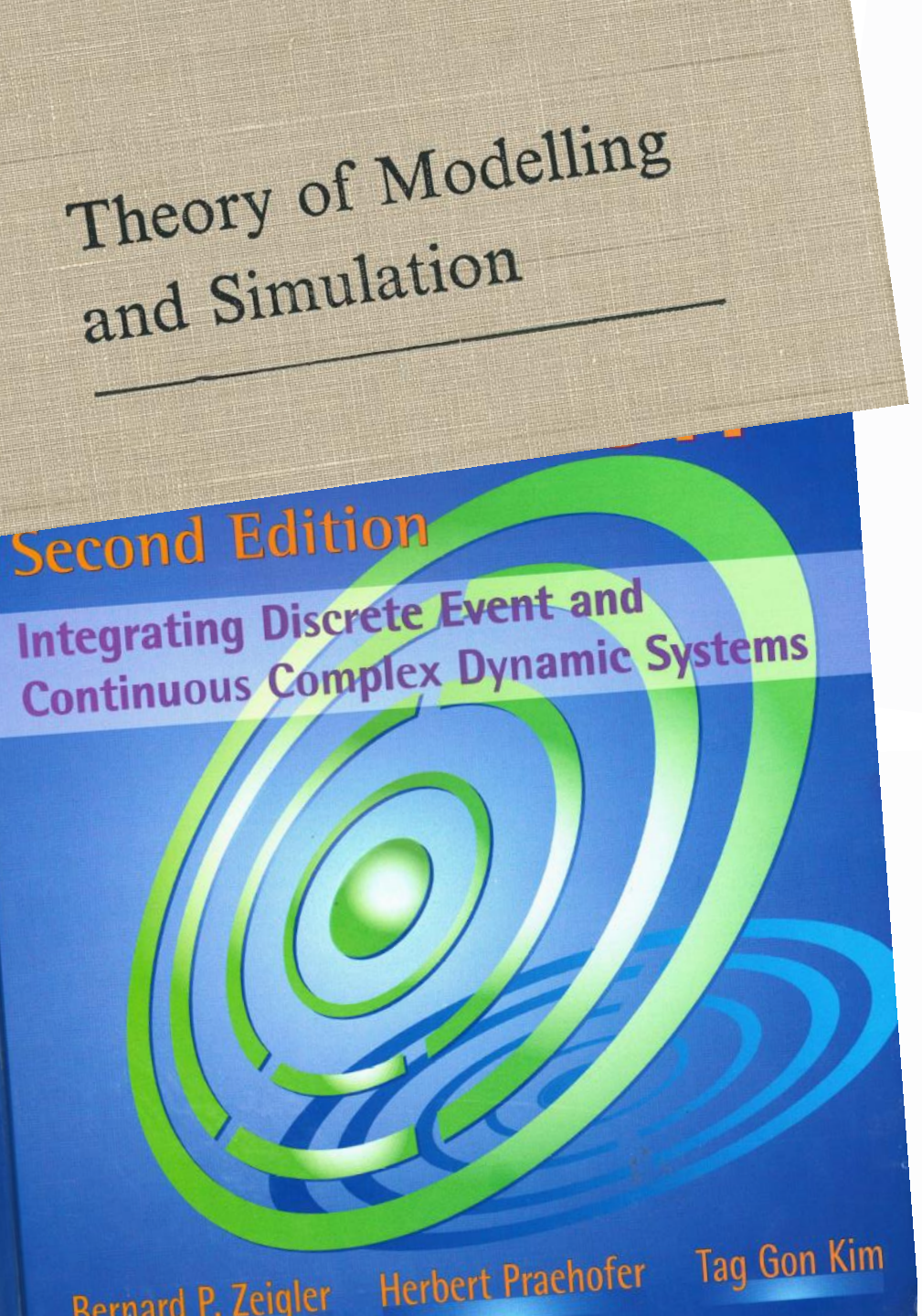
Parallel DEVS

An Introduction Using PythonPDEVS

Yentl Van Tendeloo, Hans Vangheluwe

Introduction



Parallel DEVS: A parallel, hierarchical, modular modeling formalism and its distributed simulator

A. C.-H. Chow

IBM Corporation, P.O. Box 180124, Austin, Texas 78758
Tel: 512-838-8069 FAX: 512-250-2346 E-mail: alexc@austin.ibm.com

We present a parallel, hierarchical, modular Discrete Event System Specification (P-DEVS) modeling formalism which provides a modeler with both conceptual and parallel execution benefits. The parallel formalism distinguishes between transition collisions and ordinary external events in the external transition function of DEVS models. Such separation enables us to extend the modeling capability of the collisions. The formalism also does away with the necessity for tie-breaking of simultaneously scheduled events, as embodied in the select function. We next present a design for the parallel simulation procedures needed to prove the formalism's soundness and to serve as a reference for implementation. We then discuss a prototype implementation that affords a high degree of flexibility by mechanizing the "closure under coupling" property of the Parallel DEVS formalism and the object-oriented characteristic

Keywords: System specification, discrete event simulat
simulation, distributed/parallel simulati

Abstract Simulator for the Parallel DEVS Formalism

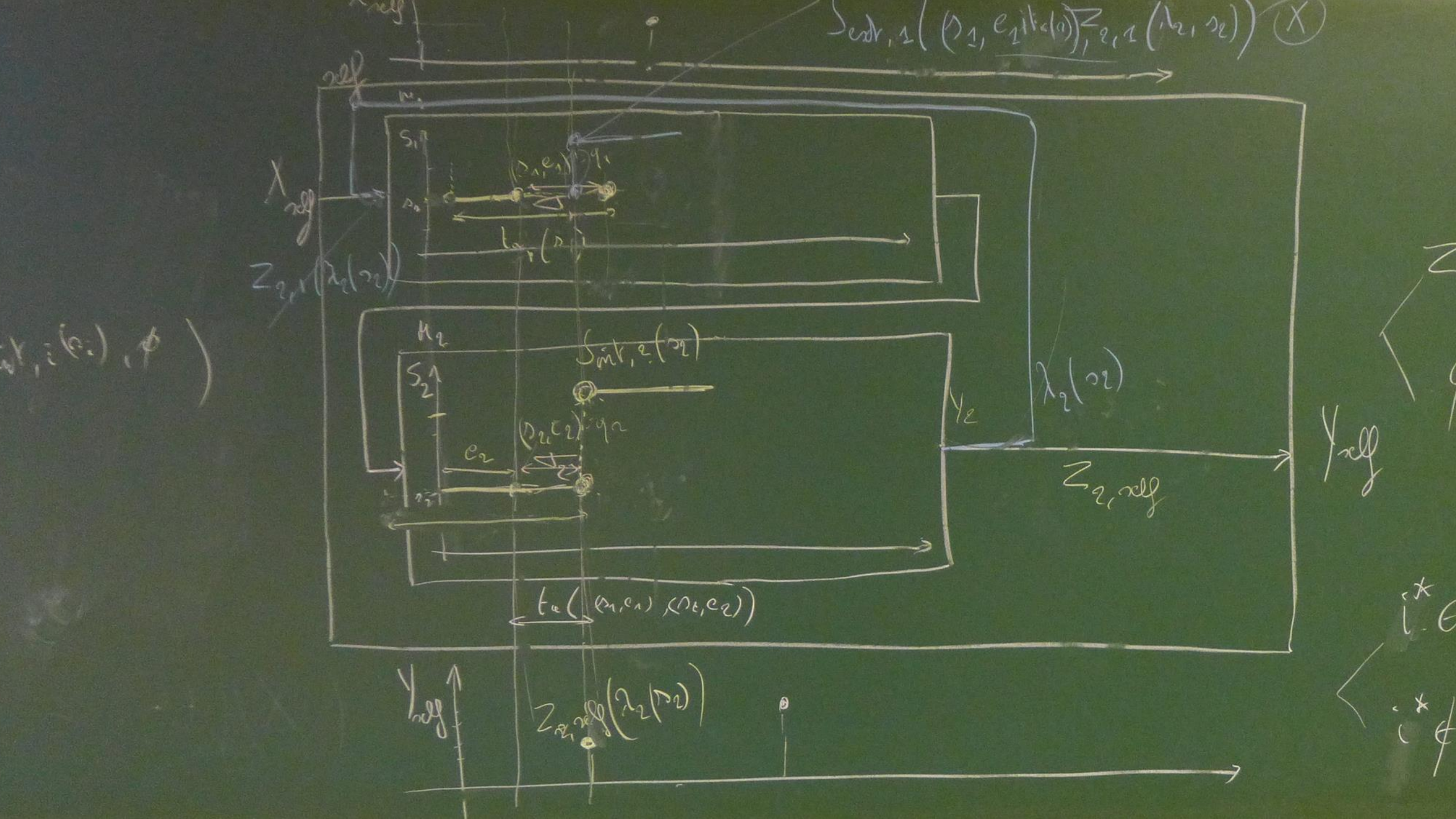
Alex ChungHen Chow

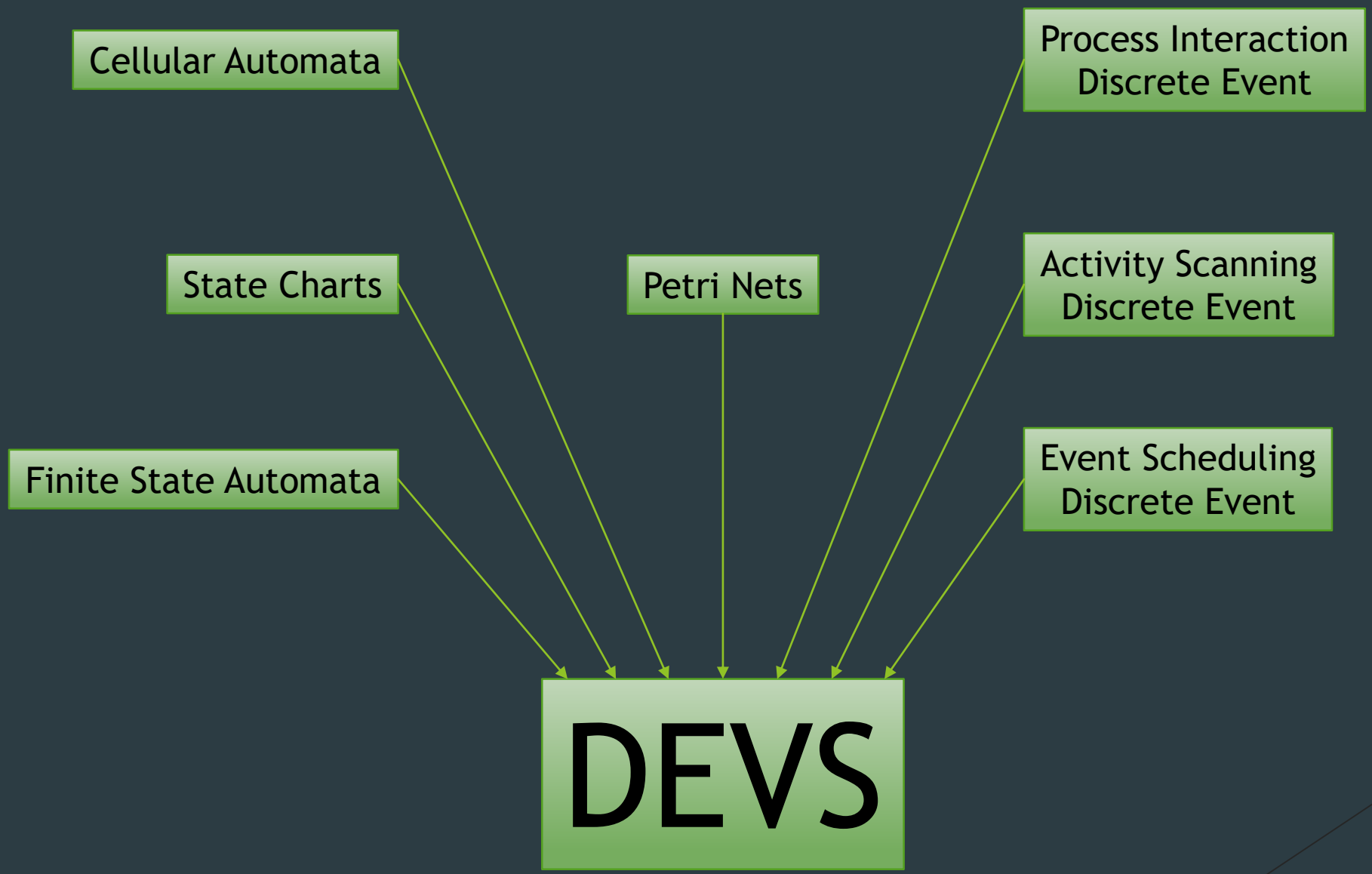
Object Technology Products

IBM Corp.
Austin, TX 78758
alexc@austin.ibm.com

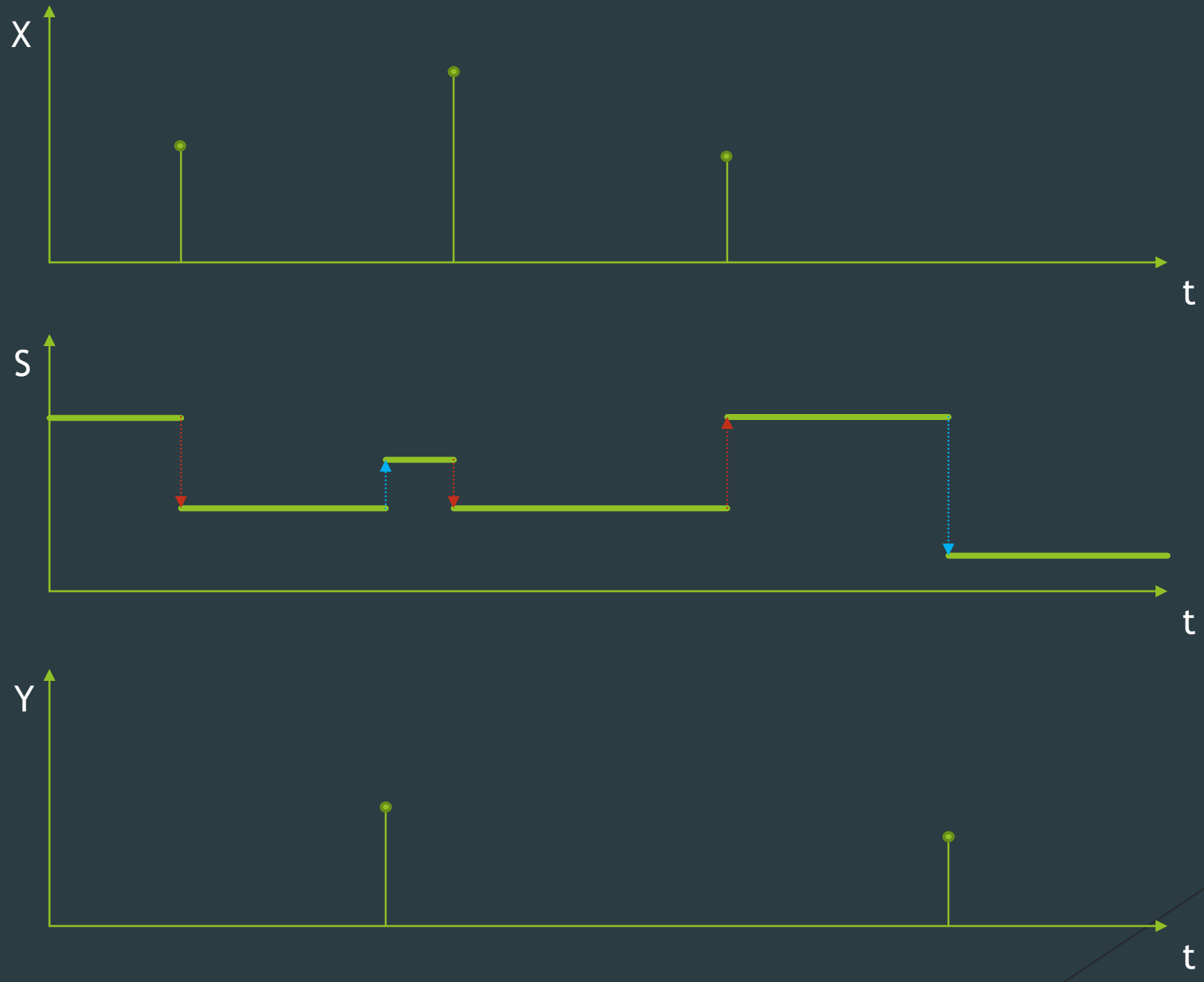
Bernard P. Zeigler
Doo Hwan Kim

Department of
Electrical and Computer Engineering
The University of Arizona
Tucson, AZ 85721
zeigler@ece.arizona.edu
dhkim@ece.arizona.edu


self
M_1
S_1
λ_{self}
(σ_1, e_1)
q_1
$t_{a,1}(\sigma_1)$
$Z_{2,1}(\lambda_2(\sigma_2))$
M_2
S_2
σ_2
e_2
(σ_2, e_2)
q_2
$t_{a,2}(\sigma_2)$
Y_2
$\lambda_2(\sigma_2)$
$Z_{2,self}$
Y_{self}
$t_a((\sigma_1,e_1),(\sigma_2,e_2))$
Y_{self}
$Z_{2,self}(\lambda_2(\sigma_2))$


Cellular Automata
State Charts
Finite State Automata
Petri Nets
Process Interaction Discrete Event
Activity Scanning Discrete Event
Event Scheduling Discrete Event
DEVS

Experimentation

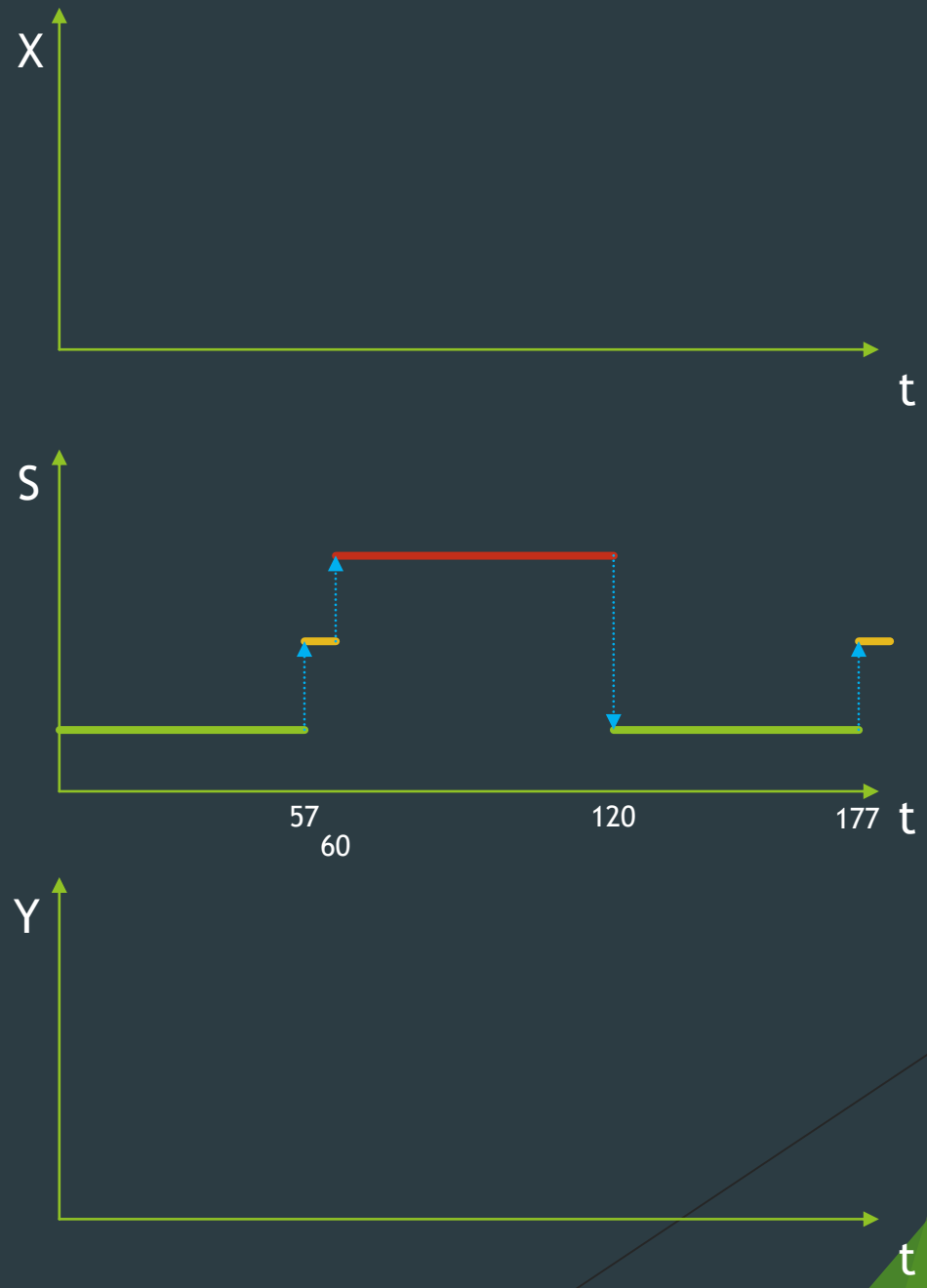

X
t
S
t
Y
t

simple_experiment.py

```
from pypdevs.simulator import Simulator

from mymodel import MyModel

model = MyModel()
simulator = Simulator(model)

simulator.setVerbose()

simulator.simulate()
```

Atomic Models


Red
60s
Yellow
3s
Green
57s


X
t
S
57
60
120
177
t
Y
t

$M = \langle\ S\ , \delta_{int}, ta\ \rangle$

S : set of sequential states

S = {Red, Yellow, Green}

$\delta_{int} : S \rightarrow S$

δ_{int} = {Red → Green,
Green → Yellow,
Yellow → Red}

$ta : S \rightarrow \mathbb{R}_{0,+\infty}$

ta = {Red → 60,
Green → 57,
Yellow → 3}

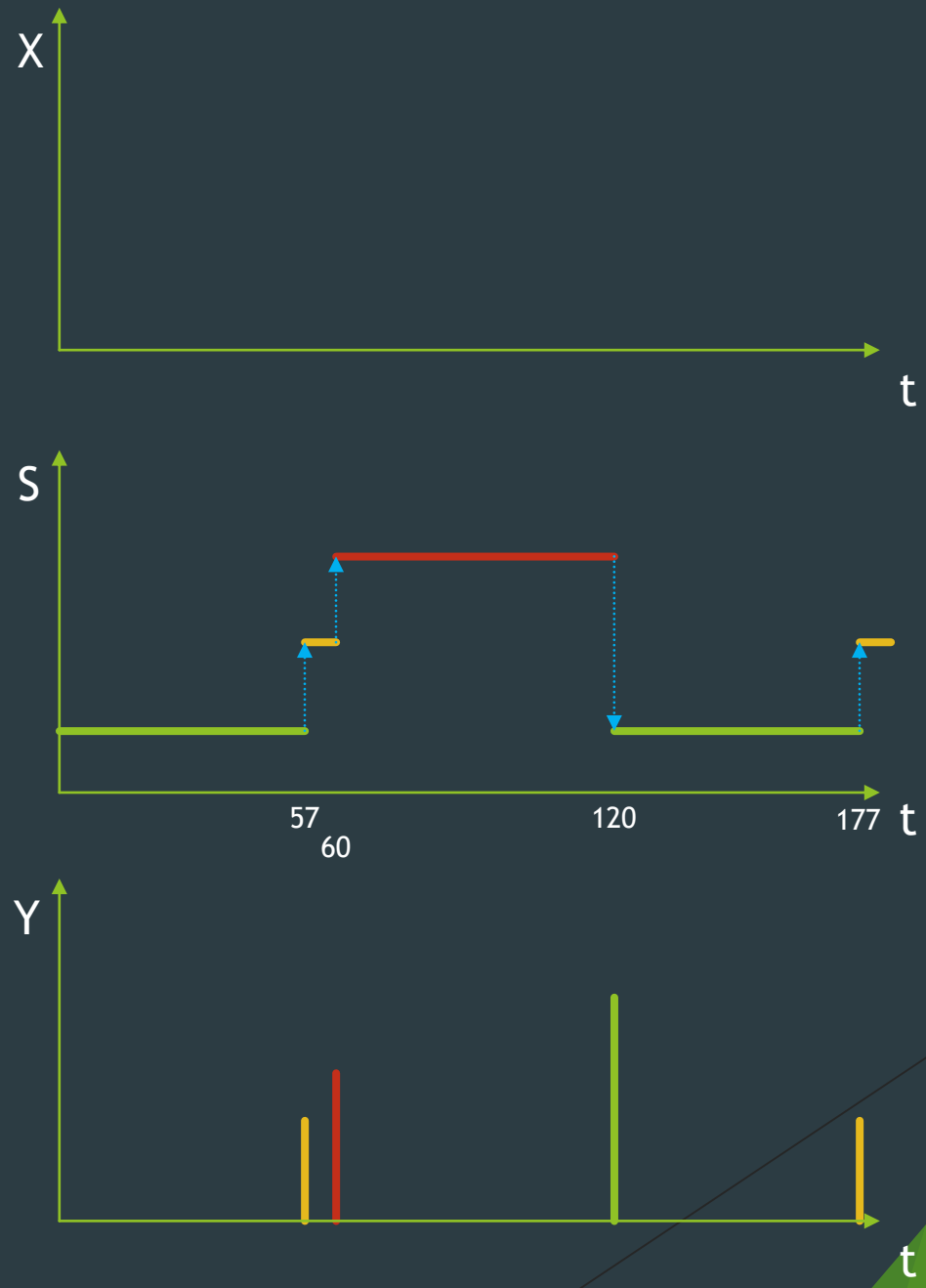
S = {Red, Yellow, Green}
δ_{int} = { Red → Green,
Green → Yellow,
Yellow → Red}
ta = {Red → 60,
Green → 57,
Yellow → 3}

```
time = 0
current_state = Green
while True:
    time += ta(current_state)
    current_state = δ_int(current_state)
```

atomic_int.py

```
from pypdevs.DEVS import *

class TrafficLightAutonomous(AtomicDEVS):
    def __init__(self):
        AtomicDEVS.__init__(self, “Light”)
        self.state = “green”

    def intTransition(self):
        state = self.state
        return {“red”: “green”,
                “yellow”: “red”,
                “green”: “yellow”}[state]

    def timeAdvance(self):
        state = self.state
        return {“red”: 60,
                “yellow”: 3,
                “green”: 57}[state]
```


Red
60s
!“red”
Yellow
3s
!“green”
!“yellow”
Green
57s


X
t
S
57
60
120
177
t
Y
t

$M = \langle Y, S, \delta_{int}, \lambda, ta \rangle$

S = {Red, Yellow, Green}

δ_{int} = { Red → Green,
Green → Yellow,
Yellow → Red}

ta = {Red → 60,
Green → 57,
Yellow → 3}

Y : set of output events

Y = {“red”, “green”, “yellow”}

$\lambda : S \rightarrow Y^b$

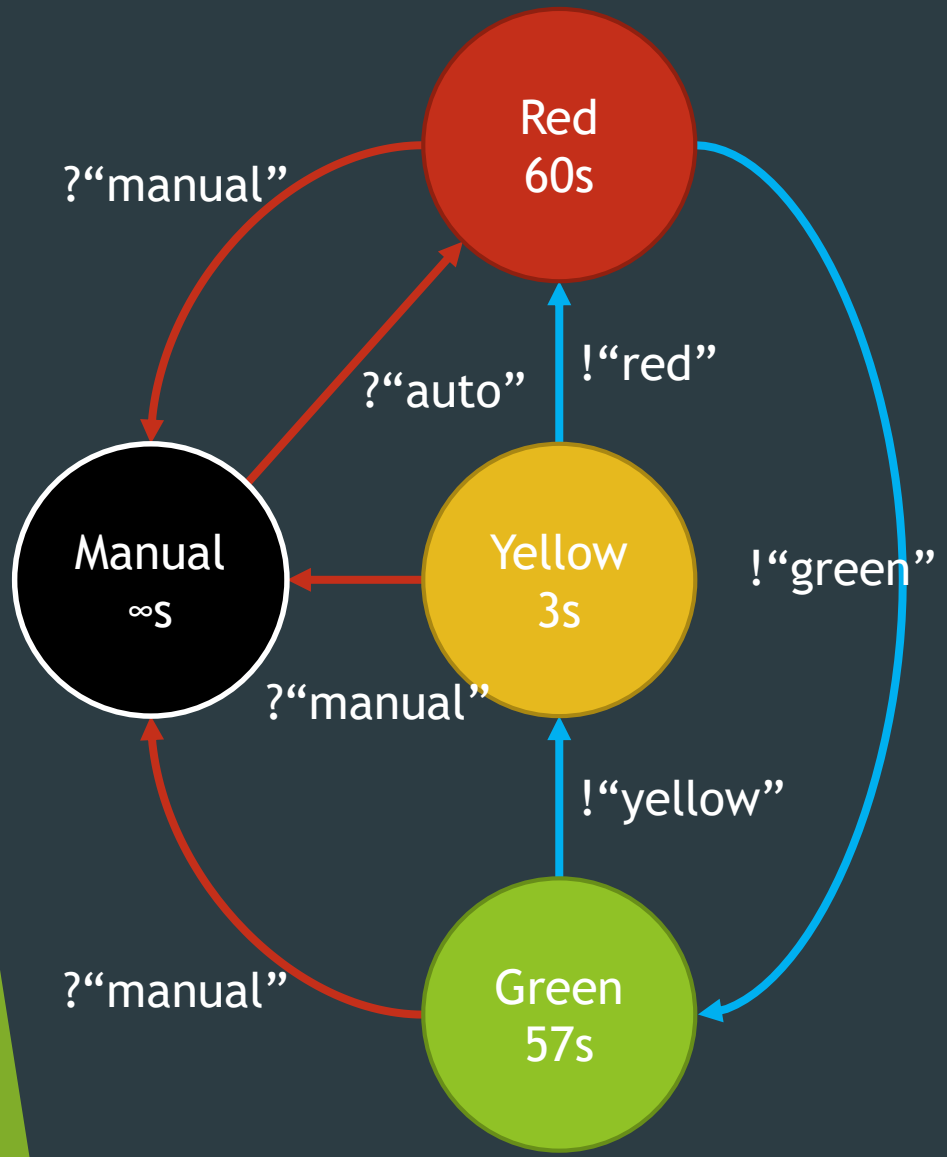
λ = { Green → [“yellow”],
Yellow → [“red”],
Red → [“green”]}

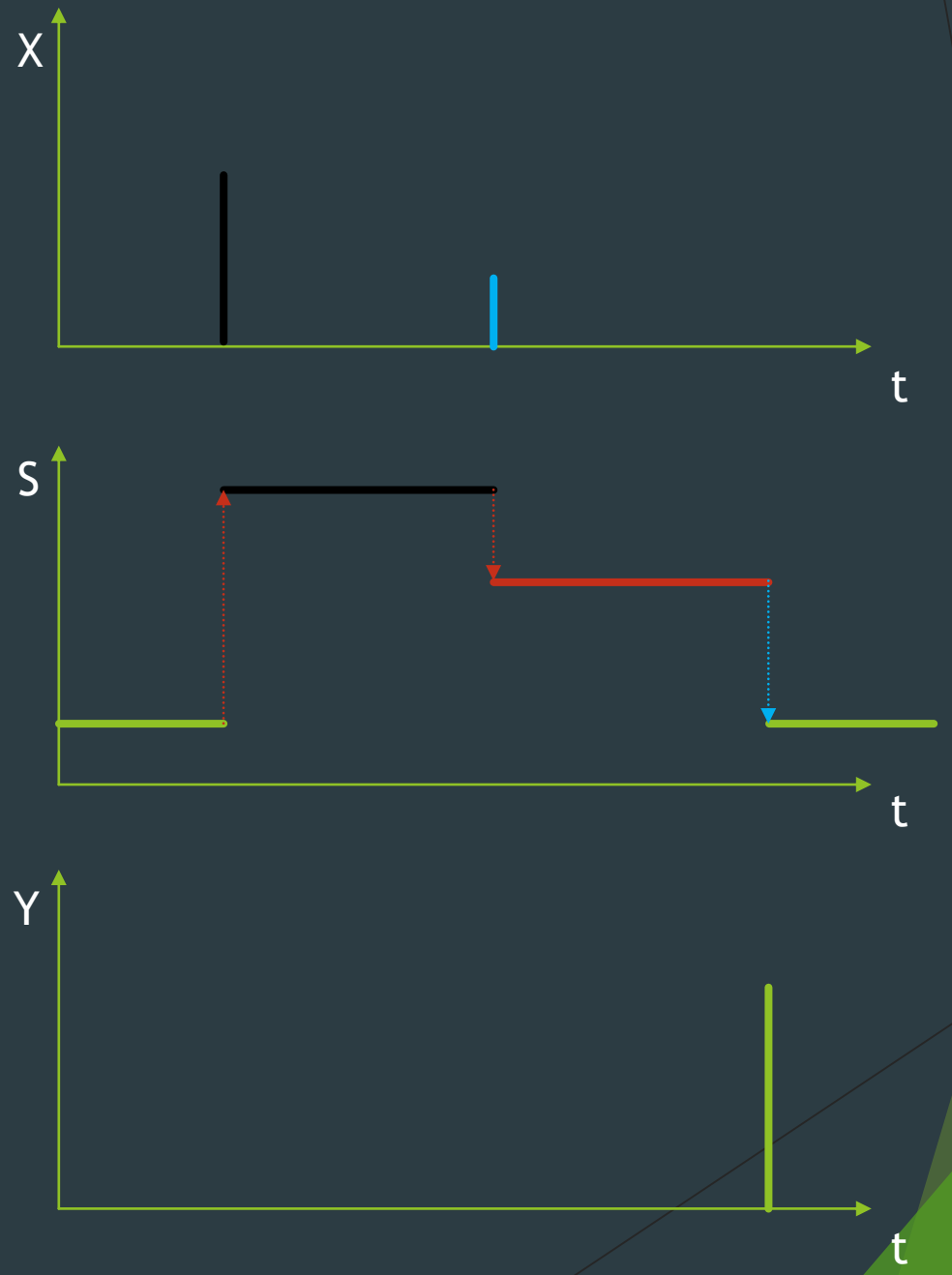
S = {Red, Yellow, Green}
δ_{int} = { Red → Green,
Green → Yellow,
Yellow → Red}
ta = {Red → 60,
Green → 57,
Yellow → 3}
Y = {“red”, “green”, “yellow”}
λ = {Green → [“yellow”],
Yellow → [“red”],
Red → [“green”]}

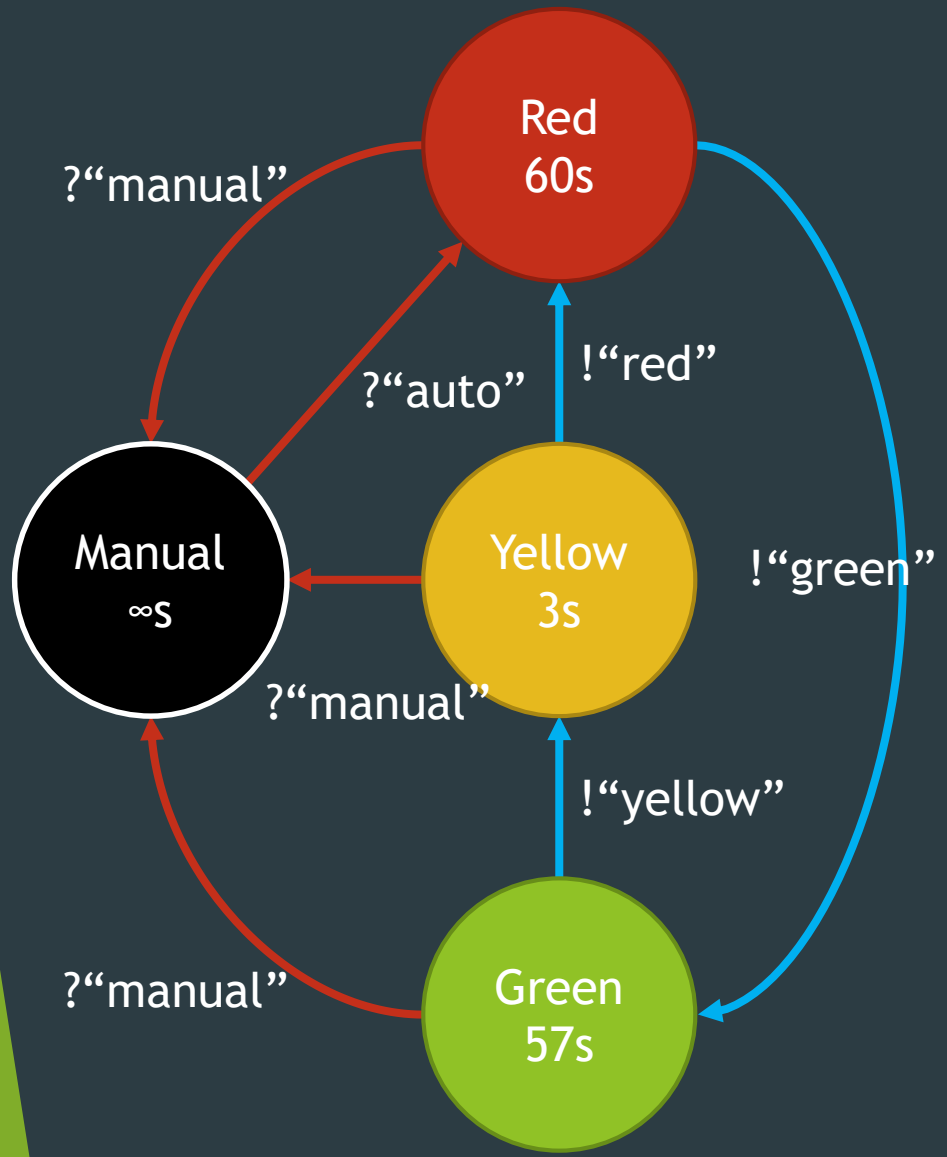
```
time = 0
current_state = Green
while True:
    time += ta(current_state)
    output(λ(current_state))
    current_state = δ_int(current_state)
```

atomic_out.py

```
from pypdevs.DEVS import *

class TrafficLightWithOutput(AtomicDEVS):
    def __init__(self):
        AtomicDEVS.__init__(self, “light”)
        self.state = “green”
        self.observe = self.addOutPort(“observer”)

    …

    def outputFnc(self):
        state = self.state
        if state == “red”:
            v = “green”
        elif state == “yellow”:
            v = “red”
        elif state == “green”:
            v = “yellow”
        return {self.observe: [v]}
```


Red
60s
?“manual”
?“auto”
!“red”
Manual
∞s
Yellow
3s
!“green”
?“manual”
!“yellow”
?“manual”
Green
57s


X
t
S
t
Y
t



$M = \langle X, Y, S, \delta_{int}, \delta_{ext}, \lambda, ta \rangle$

Y = {“red”, “green”, “yellow”}

S = {Red, Yellow, Green, Manual}

δ_{int} = {Red → Green,
Green → Yellow,
Yellow → Red}

λ = {Green → [“yellow”],
Yellow → [“red”],
Red → [“green”]}

ta = {Red → 60,
Green → 57,
Yellow → 3,
Manual → ∞}

X : set of input events

X = {“auto”, “manual”}

$\delta_{ext} : Q \times X^b \rightarrow S$

$Q = \{(s, e) | s \in S, 0 \leq e \leq ta(s)\}$

δ_{ext} = {((*, *), [“manual”]) → Manual,
((Manual, *), [“auto”]) → Red}

Y = {“red”, “green”, “yellow”}
S = {Red, Yellow, Green, Manual}
δ_{int} = {Red → Green,
Green → Yellow,
Yellow → Red}
λ = {Green → [“yellow”],
Yellow → [“red”],
Red → [“green”]}
ta = {Red → 60,
Green → 57,
Yellow → 3,
Manual → ∞}
X = {“auto”, “manual”}
δ_{ext} = {((*, *), [“manual”]) → Manual,
((Manual, *), [“auto”]) → Red}

```
time = 0
cur_state = Green
while True:
    next_time = time + ta(cur_state)
    if time_next_ev <= next_time:
        cur_state = δ_ext((cur_state, e), next_ev)
        time = time_next_ev
    else:
        time = next_time
        output(λ(current_state))
        current_state = δ_int (current_state)
```

Y = {“red”, “green”, “yellow”}
S = {Red, Yellow, Green, Manual}
δ_{int} = {Red → Green,
Green → Yellow,
Yellow → Red}
λ = {Green → [“yellow”],
Yellow → [“red”],
Red → [“green”]}
ta = {Red → 60,
Green → 57,
Yellow → 3,
Manual → ∞}
X = {“auto”, “manual”}
δ_{ext} = {((*, *), [“manual”]) → Manual,
((Manual, *), [“auto”]) → Red}

atomic_ext.py

```
from pypdevs.DEVS import *

class TrafficLight(AtomicDEVS):
 def __init__(self):
       AtomicDEVS.__init__(self, “light”)
       self.state = “green”
       self.observe = self.addOutPort(“observer”)
       self.interrupt = self.addInPort(“interrupt”)

    …

    def extTransition(self, inputs):
       inp = inputs[self.interrupt][0]
       if inp == “manual”:
          return “manual”
       elif inp == “auto”:
          if self.state == “manual”:
             return “red”
```

$$M = \langle X, Y, S, \delta_{int}, \delta_{ext}, \ \delta_{conf} \ , \lambda, ta \rangle$$

X : set of input events

Y : set of output events

S : set of sequential states

$\delta_{int} : S \to S$

$\delta_{ext}: \mathrm{Q} \times X^b \to S$

$\lambda : S \to Y^b$

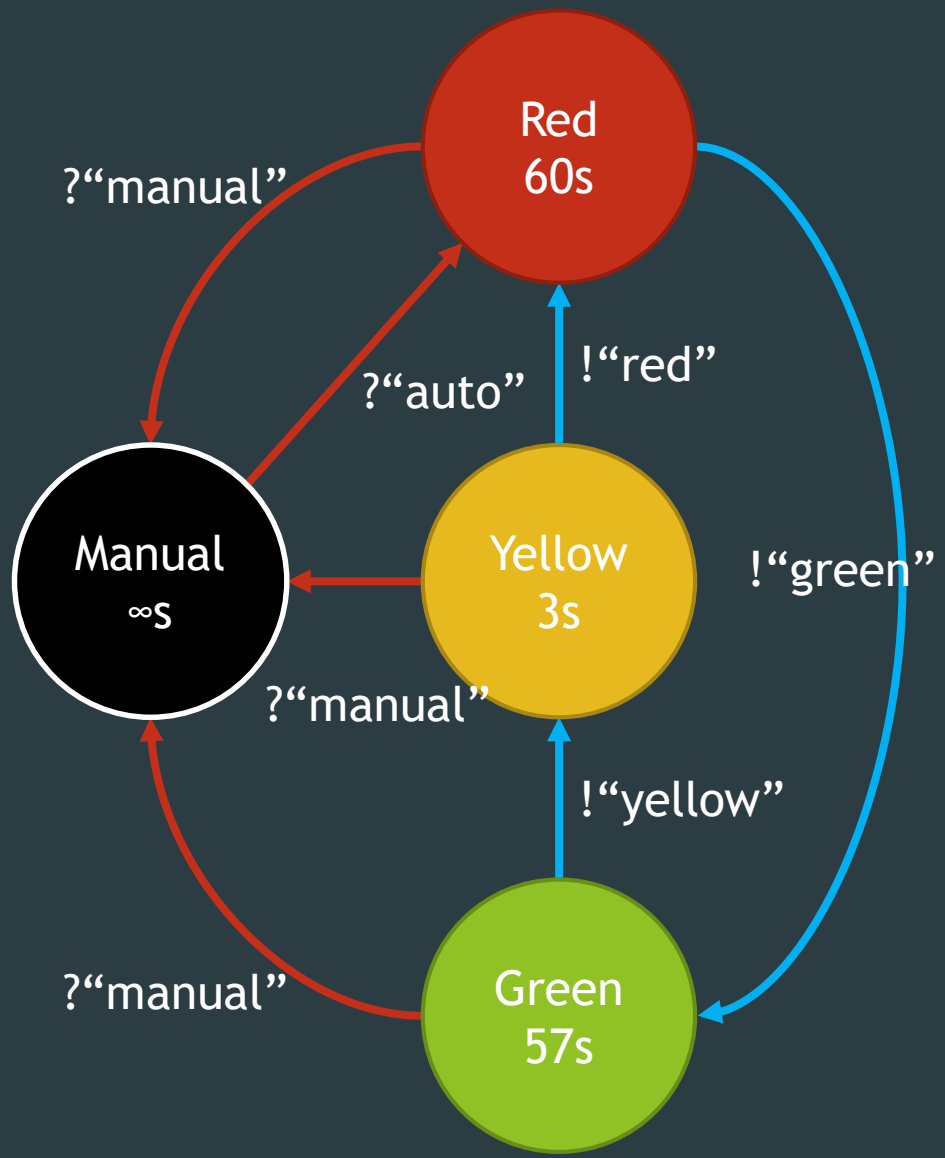
$ta : \mathrm{S} \to \mathbb{R}_{0,+\infty}$

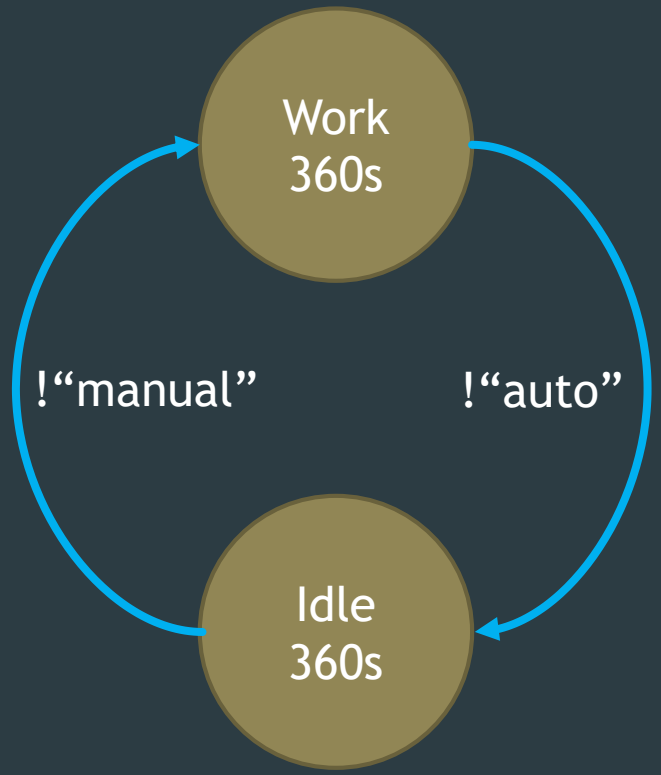
$\delta_{conf} : S \times X^b \to S$

atomic_conf.py

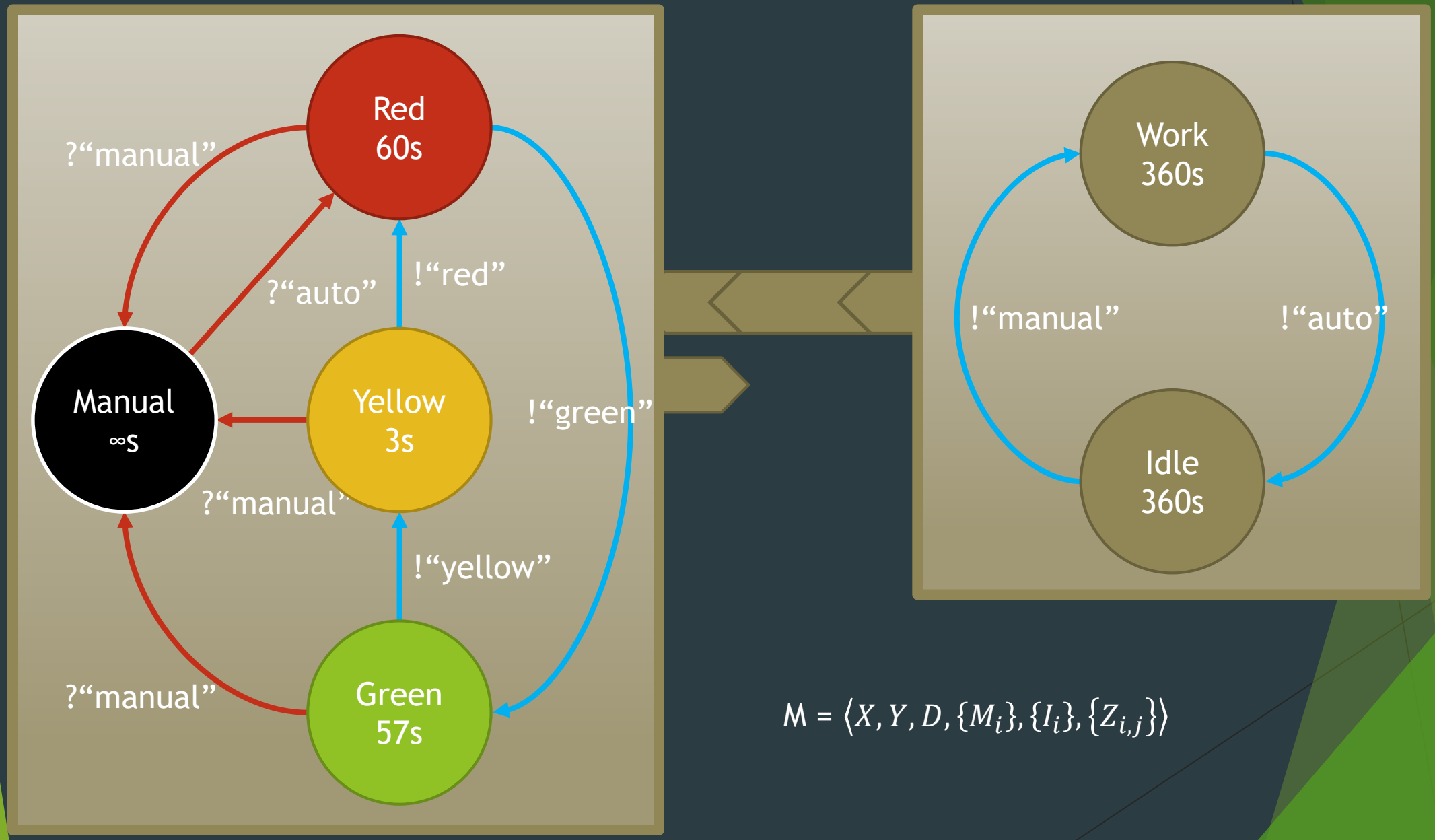
```
from pypdevs.DEVS import *

class TrafficLight(AtomicDEVS):
    …

    def confTransition(self, inputs):
        self.elapsed = 0.0
        self.state = self.intTransition()
        self.state = self.extTransition(inputs)
        return self.state
```

Coupled Models


Red
60s
?“manual”
?“auto”
!“red”
Manual
∞s
Yellow
3s
!“green”
?“manual”
!“yellow”
?“manual”
Green
57s


Work
360s
!“manual”
!“auto”
Idle
360s


TRAFFIC



$$M = \langle X, Y, D, \{M_i\}, \{I_i\}, \{Z_{i,j}\} \rangle$$

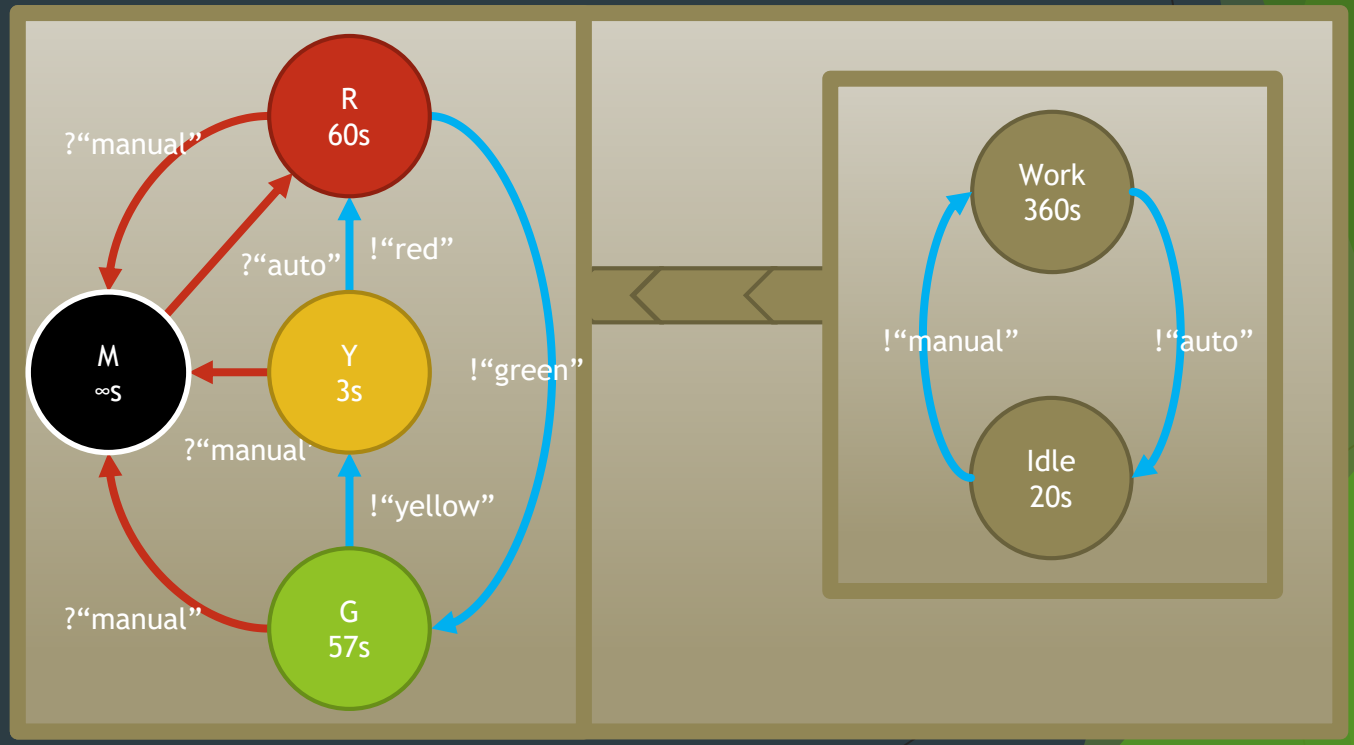
trafficlight_system.py

```
from pypdevs.DEVS import *

from trafficlight import TrafficLight
from policeman import Policeman

class TrafficLightSystem(CoupledDEVS):
    def __init__(self):
        CoupledDEVS.__init__(self, “system”)
        self.light = self.addSubModel(TrafficLight())
        self.police = self.addSubModel(Policeman())
        self.connectPorts(self.police.out, self.light.interrupt)
```

Conclusions

Conclusions

- Atomic DEVS
- Coupled DEVS



http://msdl.cs.mcgill.ca/projects/PythonPDEVS