MDE: Modelling the DEVS formalism

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The problem: Difficult to comprehend

```
class Root(CoupledDEVS):
  def __init__(self):
    CoupledDEVS.__init__(self)
    self.gen = self.addSubModel(Generator())
    self.seg1 = self.addSubModel(RoadSegment())
    self.seg2 = self.addSubModel(RoadSegment())
    self.seg3 = self.addSubModel(RoadSegment())
    self.col = self.addSubModel(Collector())
    self.connectPorts(self.gen.Q_send, self.seg1.Q_recv)
    self.connectPorts(self.gen.car_out, self.seg1.car_in)
    self.connectPorts(self.seg1.Q_sack, self.gen.Q_rack)
    self.connectPorts(self.seg1.Q_send, self.seg2.Q_recv)
    self.connectPorts(self.seg1.car_out, self.seg2.car_in)
    self.connectPorts(self.seg2.Q_sack, self.seg1.Q_rack)
    self.connectPorts(self.seg2.Q_send, self.seg3.Q_recv)
    self.connectPorts(self.seg2.car_out, self.seg3.car_in)
    self.connectPorts(self.seg3.Q_sack, self.seg2.Q_rack)
    self.connectPorts(self.seg3.car_out, self.col.car_in)
```

The problem: Difficult to comprehend

```
class Root(CoupledDEVS):
  def __init__(self):
    CoupledDEVS.__init__(self)
    self.gen = self.addSubModel(Generator())
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    self.connectPorts(self.gen.Q_send, self.seg1.Q_recv)
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    self.connectPorts(self.seg1.car_out, self.seg2.car_in)
    self.connectPorts(self.seg2.Q_sack, self.seg1.Q_rack)
    self.connectPorts(self.seg2.Q_send, self.seg3.Q_recv)
    self.connectPorts(self.seg2.car_out, self.seg3.car_in)
    self.connectPorts(self.seg3.Q_sack, self.seg2.Q_rack)
    self.connectPorts(self.seg3.car_out, self.col.car_in)
```

Solution: Graphical representation

The problem: Different simulators

```
int main(int, char** argv){
  adevs::Digraph<Event*> dig;
  Generator* gen = new Generator();
  RoadSegment* seg1 = new RoadSegment();
  RoadSegment* seg2 = new RoadSegment();
  RoadSegment* seg3 = new RoadSegment();
  Collector* col = new Collector();
  dig.add(gen);
  dig.add(seg1);
  dig.add(seg2);
  dig.add(seg3);
  dig.add(col);
  dig.couple(gen, gen->Q_send, seg1, seg1->Q_recv);
  dig.couple(gen, gen->car_out, seg1, seg1->car_in);
  dig.couple(seg1, seg1->Q_sack, gen, gen->Q_rack);
  dig.couple(seg1, seg1->Q_send, seg2, seg2->Q_recv);
  dig.couple(seg1, seg1->car_out, seg2, seg2->car_in);
  dig.couple(seg2, seg2->Q_sack, seg1, seg1->Q_rack);
  dig.couple(seg2, seg2->Q_send, seg3, seg3->Q_recv);
  dig.couple(seg2, seg2->car_out, seg3, seg3->car_in);
  dig.couple(seg3, seg3->Q_sack, seg2, seg2->Q_rack);
  dig.couple(seg3, seg3->car_out, col, col->car_in);
```

The problem: Different simulators

```
int main(int, char** argv){
  adevs::Digraph<Event*> dig;
  Generator* gen = new Generator();
  RoadSegment* seg1 = new RoadSegment();
  RoadSegment* seg2 = new RoadSegment();
  RoadSegment* seg3 = new RoadSegment();
  Collector* col = new Collector();
  dig.add(gen);
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  dig.couple(gen, gen->Q_send, seg1, seg1->Q_recv);
  dig.couple(gen, gen->car_out, seg1, seg1->car_in);
  dig.couple(seg1, seg1->Q_sack, gen, gen->Q_rack);
  dig.couple(seg1, seg1->Q_send, seg2, seg2->Q_recv);
  dig.couple(seg1, seg1->car_out, seg2, seg2->car_in);
  dig.couple(seg2, seg2->Q_sack, seg1, seg1->Q_rack);
  dig.couple(seg2, seg2->Q_send, seg3, seg3->Q_recv);
  dig.couple(seg2, seg2->car_out, seg3, seg3->car_in);
  dig.couple(seg3, seg3->Q_sack, seg2, seg2->Q_rack);
  dig.couple(seg3, seg3->car_out, col, col->car_in);
```
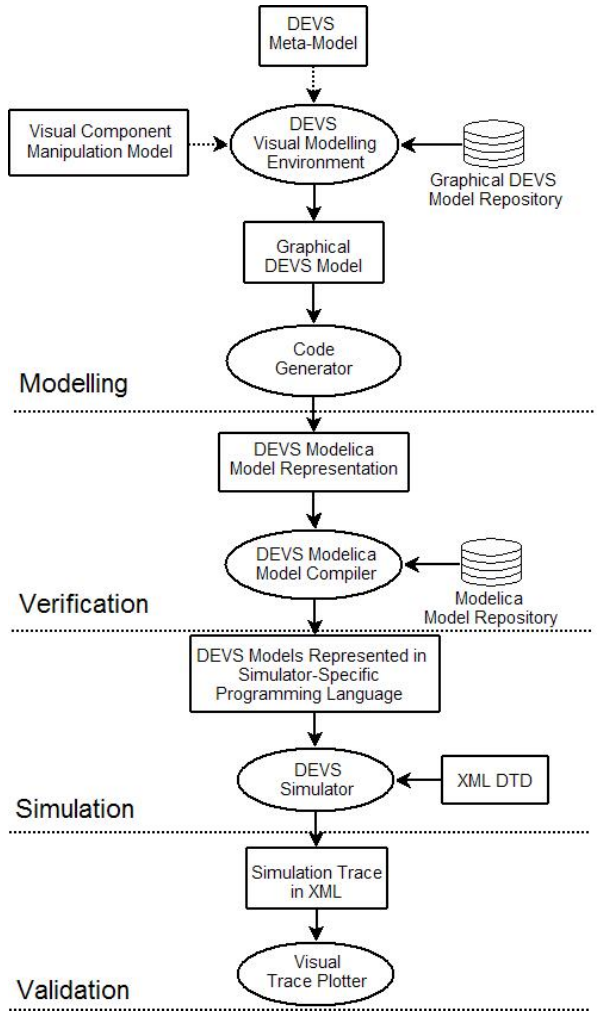

Solution: Independent language

Global overview



Source: Hongyan Song. Infrastructure for devs modelling and experimentation. Master's thesis, McGill University, 2006

Overview: Modelling

- In *AToM*^{3}
- Compliant to a metamodel
- Should have a *code generation* feature
  - For intermediate language (*Modelica*)
- Automatically generated environment!

Intermediate Language: Modelica

Modelling language

- Relatively mature
- Language features for both continuous and discrete models
- Standard library
- Re-usability

Modelica Example

```
class Generator
  extends AtomicDEVS;
  output DevsPort p_out;
  GeneratorState state();

  function timeAdvance
    output Integer timespan;
  algorithm
    ...
  end timeAdvance;
end Generator;

class Root
  extends CoupledDEVS;
  output DevsPort p_out;
  Processor ins_2();
equation
  connect( ins_2.p_out , p_out);
end Root;
```

Overview: Verification

- Use the μModelica compiler [1]
- Statically check the model
  - No accesses to inaccessible variables
- Possibly perform optimisations
- Currently (nearly) no verification happens

[1] Weigao Xu. The design and implementation of the modelica compiler. Master's thesis, McGill University, 2005

Overview: Simulation

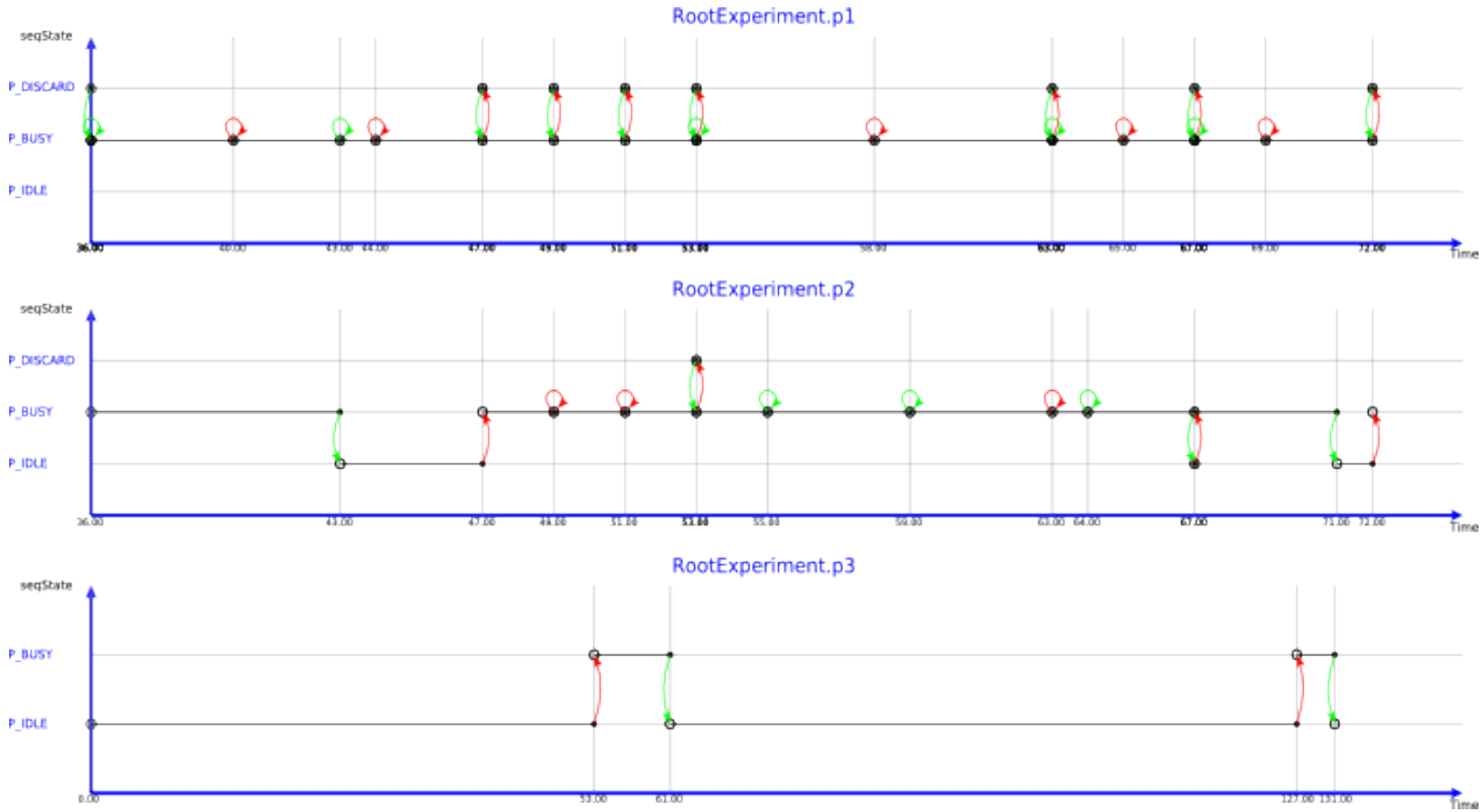
- Use the PythonDEVS simulator [2]
- Save the trace file
  - Text output
  - XML output
  - VCD output

[2] Jean-Sébastien Bolduc and Hans Vangheluwe. The modelling and simulation package pythondevs for classical hierarchical devs. Technical report, MSDL Technical Report, 2001

Overview: Validation

- Compare the output of the simulation to the specifications
- Textual simulation traces are unclear
- Visualize!

Overview: Validation (example)



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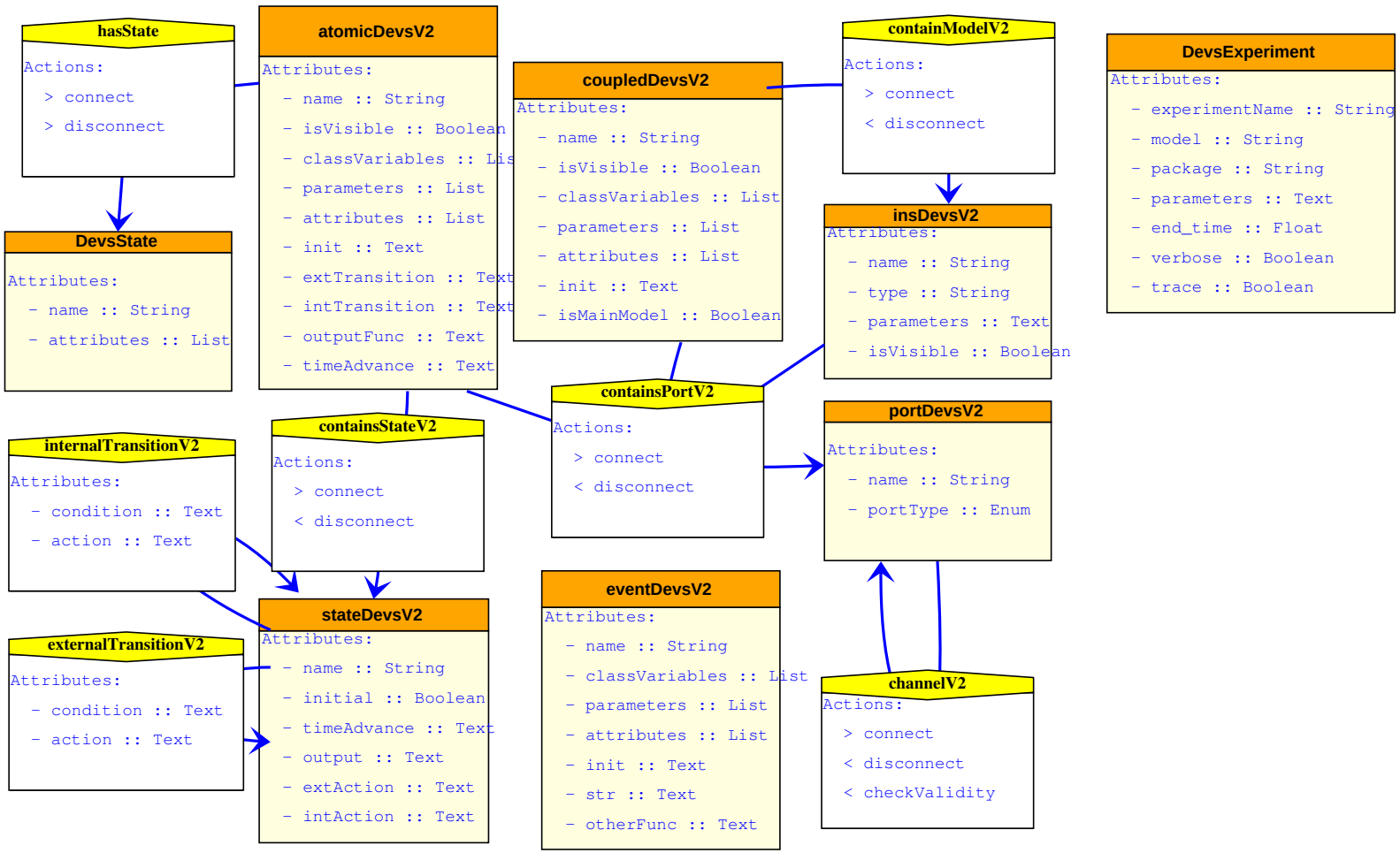
Overview: Features

- Model reuse
  - At *AToM*^{3} level
  - At *Modelica* level
  - At *PythonDEVS* level
- Clear boundaries
- Open structure

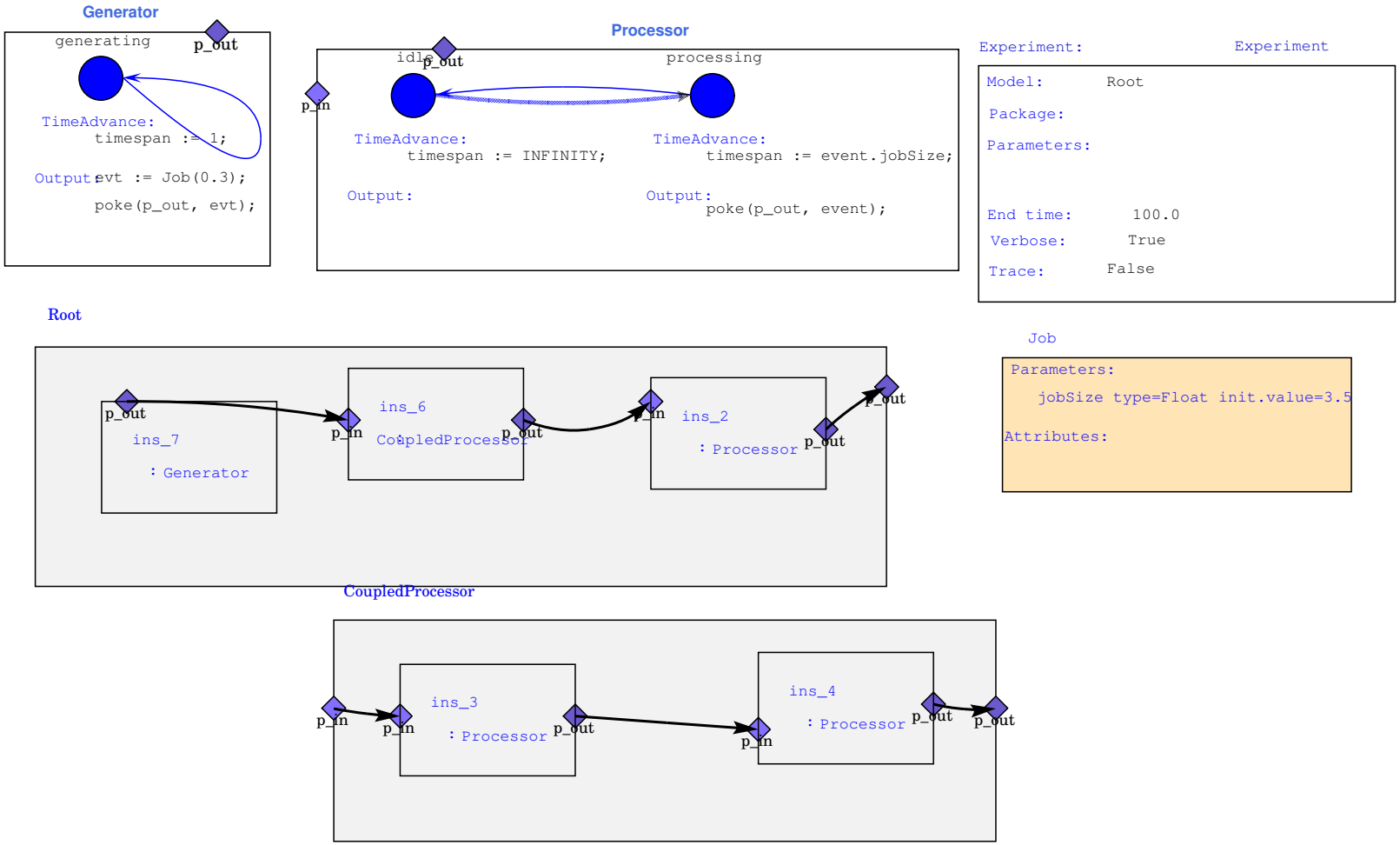
My contribution

- Modelling
  - Updating the existing metamodel
  - Include experiment data
- Verification
  - Update the μModelica compiler
  - Introduce a flattening phase

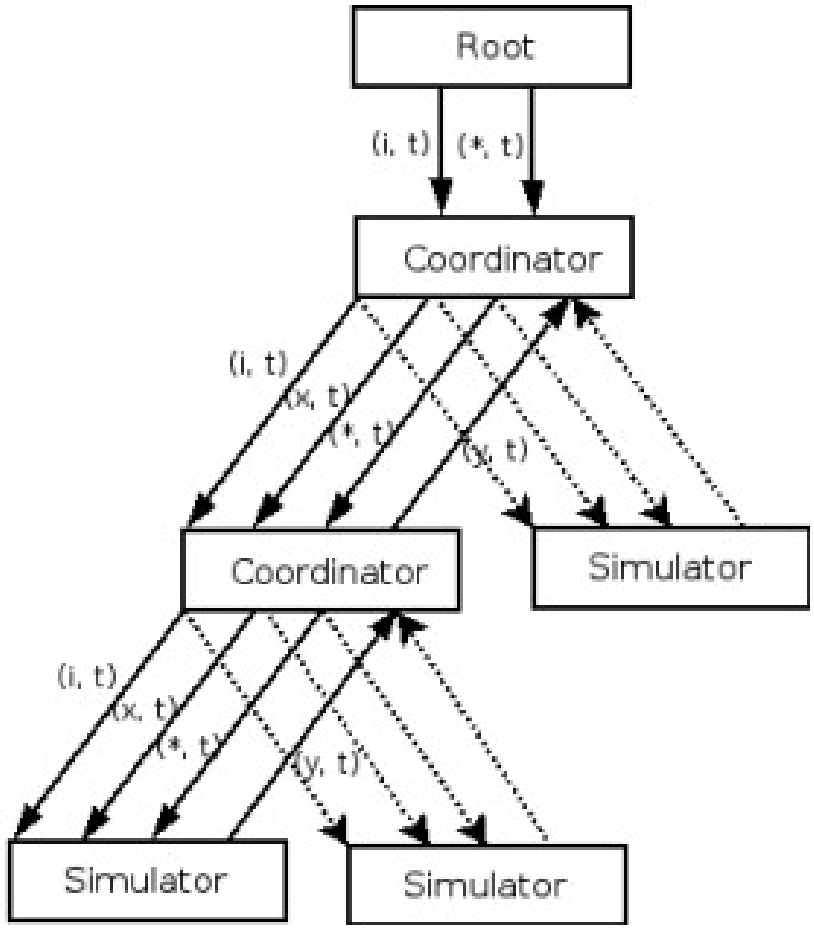
Modelling in *AToM*^{3}: metamodel



Modelling in *AToM*^{3}: example model



DEVS: Messages



Verification: Flattening

- What is flattening?
  - Perform the closure under coupling on a real model
  - Together with *direct connection*
- Use of flattening
  - Increased performance
  - The proof was right!

Verification: Direct connection

- What is direct connection?
  - Remove the complete hierarchy
  - Just 1 coupled model
  - Connections become 'one-step'
- Problems! [3]
  - Z functions need to be rewritten
  - select functions need to be rewritten

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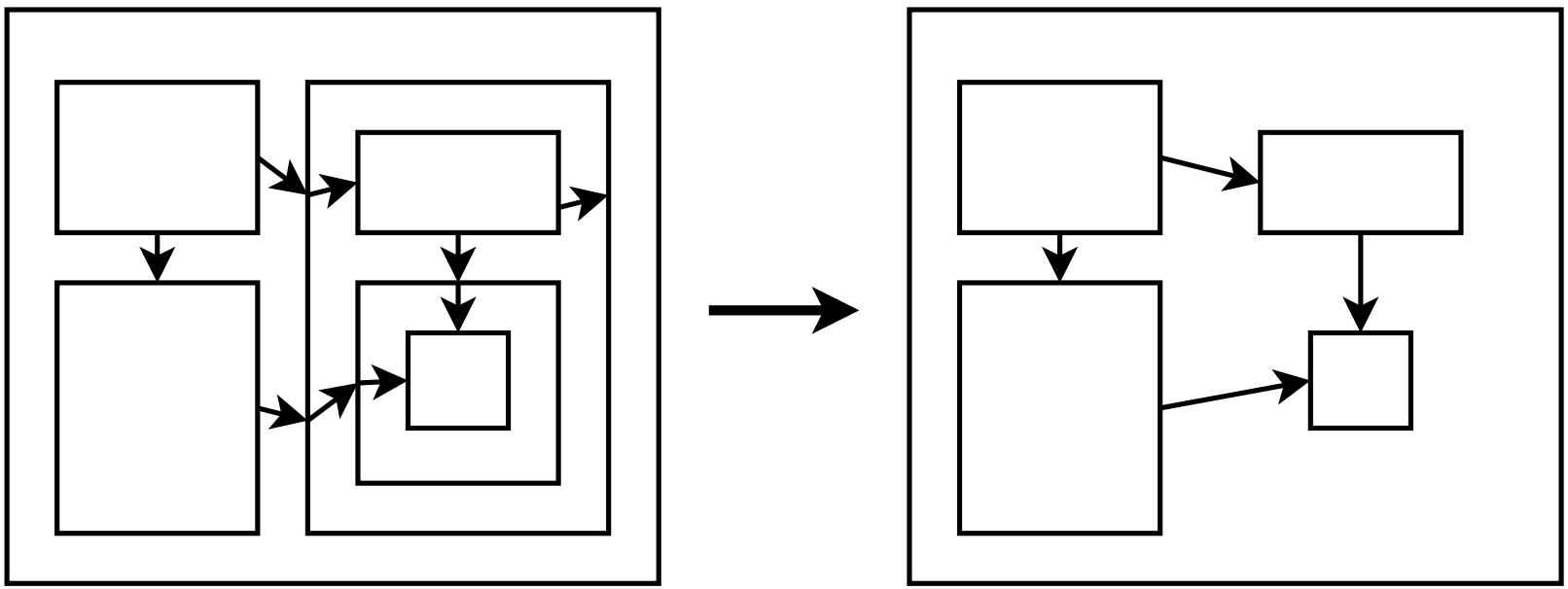
[3] Bin Chen and Hans Vangheluwe. Symbolic flattening of devs models. In *2010 Summer Simulation Multiconference*, SummerSim '10, pages 209–218, San Diego, CA, USA, 2010. Society for Computer Simulation International

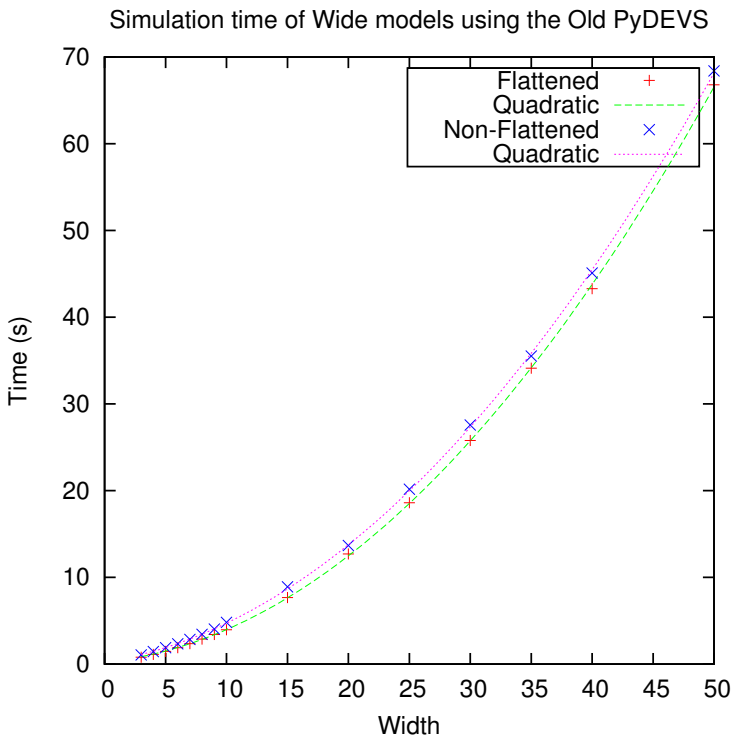
Verification: Direct connection

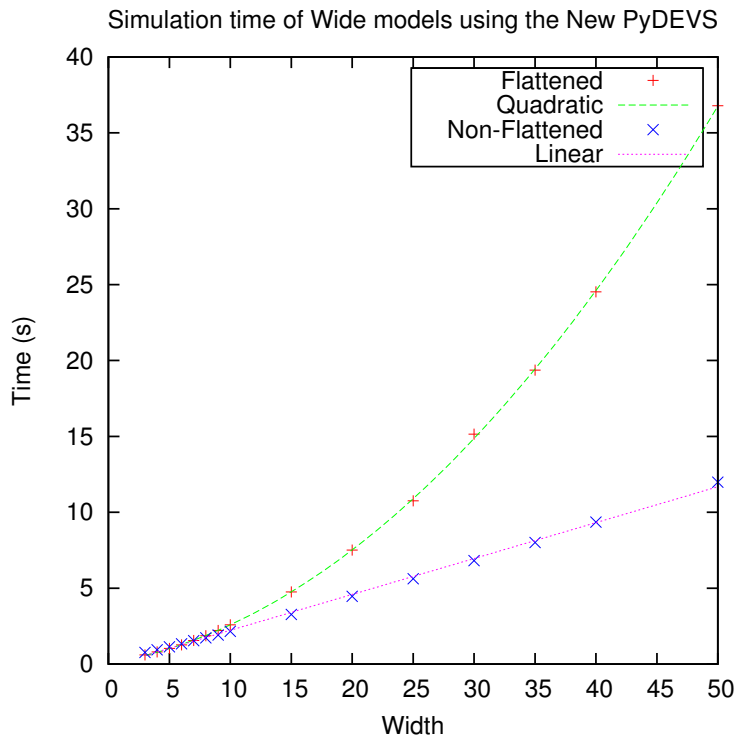


Verification: Compilation

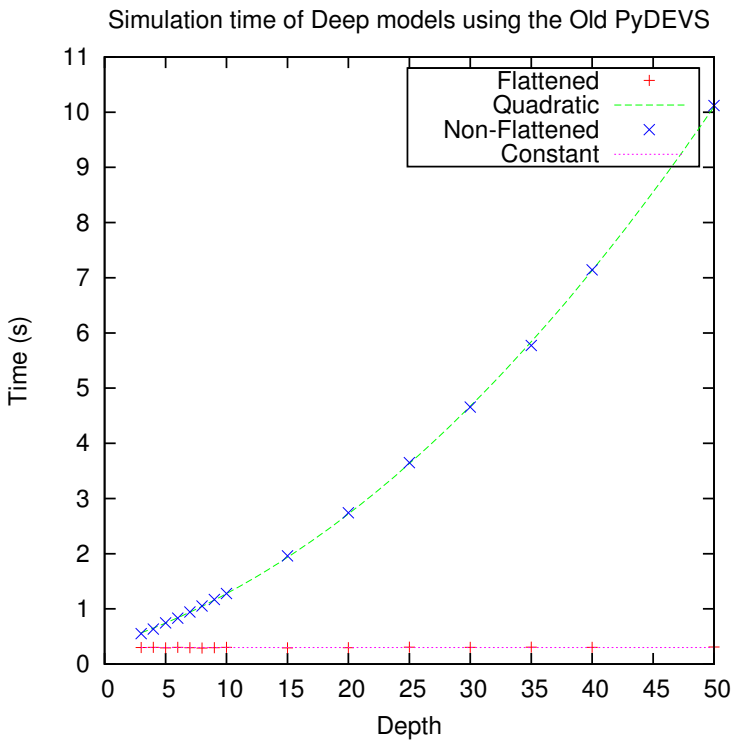
- Still need to compile the generated modelica code
- Some slight changes were done here

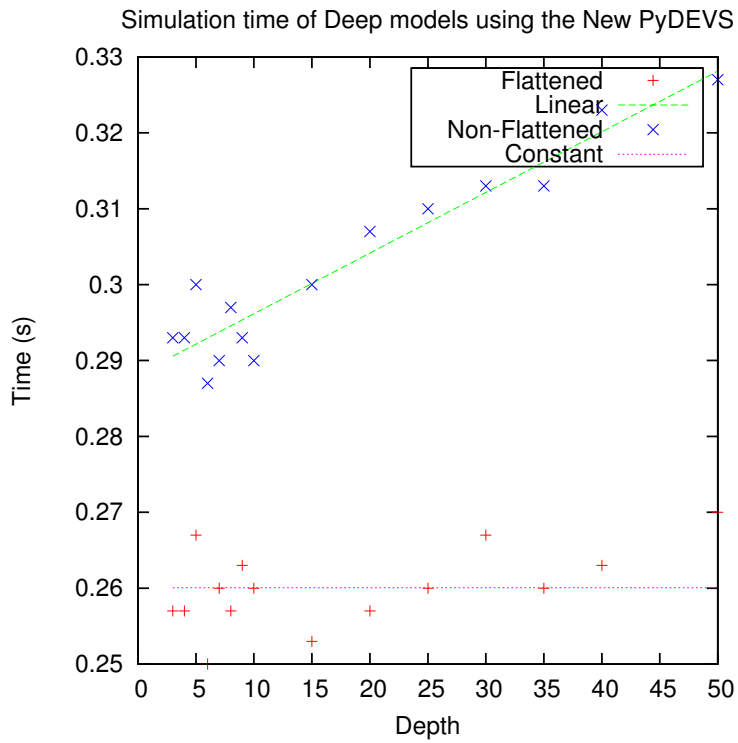
Evaluation


Simulation time of Wide models using the Old PyDEVS
Time (s)
Width
Flattened Quadratic
Non-Flattened Quadratic
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30
35
40
45
50


Simulation time of Wide models using the New PyDEVS
Time (s)
Width
Flattened Quadratic
Non-Flattened Linear
0
5
10
15
20
25
30
35
40
0
5
10
15
20
25
30
35
40
45
50

Evaluation


Simulation time of Deep models using the Old PyDEVS
Time (s)
Depth
Flattened
Quadratic
Non-Flattened
Constant
0
1
2
3
4
5
6
7
8
9
10
11
0
5
10
15
20
25
30
35
40
45
50


Simulation time of Deep models using the New PyDEVS
Time (s)
Depth
Flattened
Linear
Non-Flattened
Constant
0.25
0.26
0.27
0.28
0.29
0.3
0.31
0.32
0.33
0
5
10
15
20
25
30
35
40
45
50

Evaluation: Gain

These optimisations are *simulator-independent*!

- Optimisations will propagate
- Difference depends on the simulator

This comparison was with an *optimised* simulator [4]

[4] Yentl Van Tendeloo. Research internship 1: Optimizing pydevs. Technical report, MSDL, 2013

Future work

Different dimensions

- Optimise flattening
- Implement Verifications
- Implement other back-ends
- Some 'details' were ignored
  - Z and select function

Demo

Time for a demo!


Jean-Sébastien Bolduc and Hans Vangheluwe.
The modelling and simulation package pythondevs for classical hierarchical devs.
Technical report, MSDL Technical Report, 2001.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