The use of the UML within the modelling process of Modelica-models

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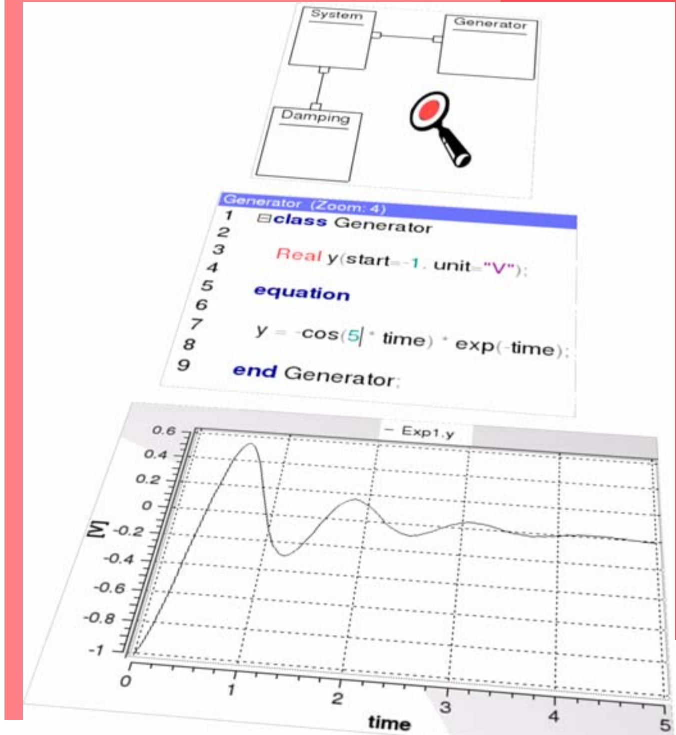
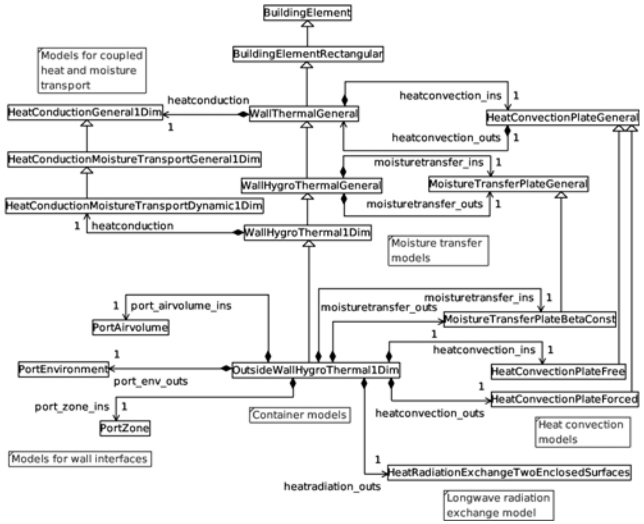


Overview

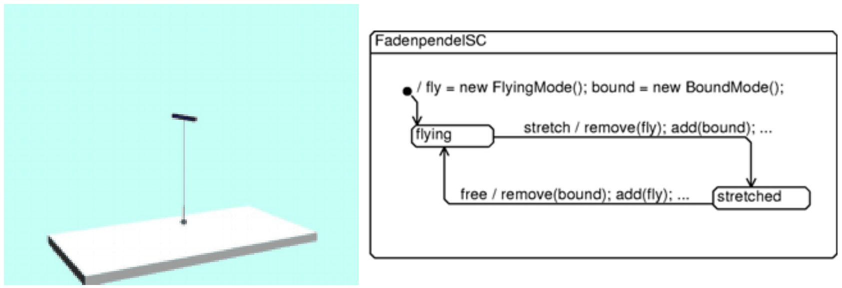
- **UML^H and Modelica**
  - Class diagrams
  - Collaboration diagrams
  - Statechart diagrams
- **Example for UML^H-modelling**
  - Model of a Pool-Billiard game
  - Simulation experiment
- **Simulation tool MOSILAB**
  - IDE for UML^H-modelling

Motivation

- **UML**^{H}: Unified **M**odeling **L**anguage
  for **H**ybrid systems
- **Advantages for UML in the Modelica context**
  - UML offers different views on OO-models
    1. Class diagrams
    2. Collaboration diagrams
    3. Statechart diagrams
  - Modelling of complex systems mostly based on complex model structures
  - UML-IDEs can generate the "basic" Modelica-code



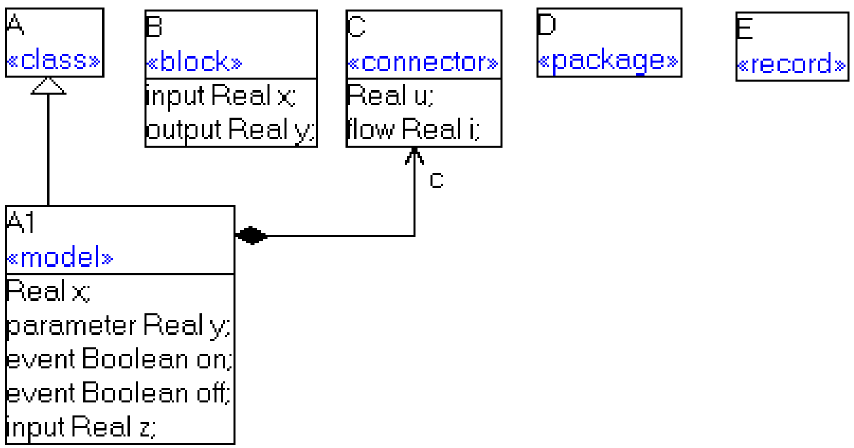
Class diagram of a hygrothermal wall model



Statechart diagram of a string pendulum

UML^{H}: Class diagrams

1. **Class types**: Model, Block, Connector, …
2. **Class attributes**: Variables, Parameter
3. **Class relations**: Inheritance, Composition



UML^{H}-class diagram

```
package UML_H annotation(UMLH(ClassDiagram="<umlhclass><name>…);
  class A annotation(UMLH(classPos=[31,53]));
  end A;
  model A1 annotation(Icon(Text(extent=…, string="A1", …));
    annotation(UMLH(classPos=[31,146]));
    extends A;
    event Boolean on;
    event Boolean off;
    Real x;
    input Real z;
    parameter Real y;
    C c;
    ...
  end A1;
  ...
  connector C annotation(UMLH(classPos=[192,54]));
    Real u;
    flow Real i;
  end C;
  ...
end UML_H;
```

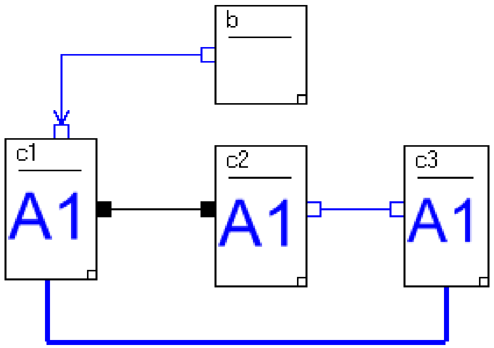
annotations hold the graphical class diagram information

Modelica code

UML^H: Component diagrams

Different connection types

1. **Connector variables**
(thin black line with filled squares at the ends)
2. **Scalar variables**
(thin blue line with unfilled squares at the ends)
3. **Scalar input/output variables** (thin blue line with an arrow and an unfilled square)
4. **Mixture connection types** of 1. to 3. (fat blue line)



UML^H-component diagram

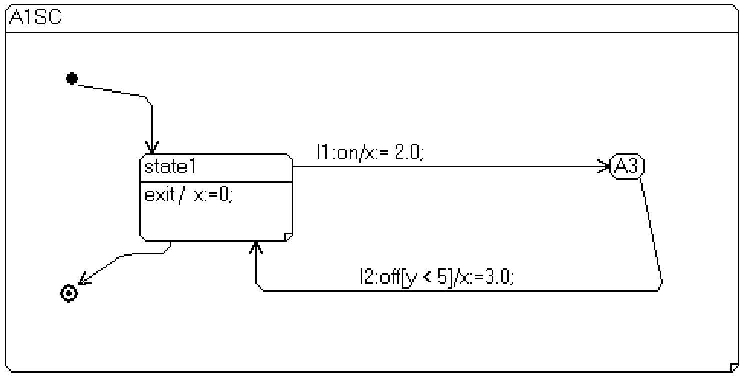
```
model System
  annotation(CompConnectors(CompConn(label="label2",
             points=[-81,52; -81,43; -24,43; -24,51])));
  UML_H.A1 c1 annotation(extent=[-87,72; -74,52]);
  UML_H.A1 c2 annotation(extent=[-57,71; -44,51]);
  UML_H.A1 c3 annotation(extent=[-30,71; -18,51]);
  UML_H.B b annotation(extent=[-57,91; -44,77]);
equation
    // connection type 1:
    connect(c1.c,c2.c)annotation(points=[-74,62;-57,62]);
    // connection type 2:
    c2.y=c3.y annotation(points=[-44,62; -30,62]);
    // connection type 3:
    b.y=c1.z annotation(points=[-57,84; -79,84; -79,72]);
    // connection type 4 (mixture of type 1 and 2):
    connect(c1.c,c3.c) annotation(label="label2");
    c1.x=c3.x annotation(label="label2");
end System;
```

Modelica code

UML^H: Statechart diagrams

Different state types

1. **Initial states** (black filled circle)
2. **Final states** (point in a unfilled circle)
3. **Atomic states** (flat internal structure)
4. **Normal states** (can contain additional entry or exit actions and can be sub-structured in further statechart diagrams)



UML^H-Statechart diagram

```
model A1  ...
statechart
  state A1SC extends State annotation(extent=[-88,86; 32,27]);
  state State1
    extends State;
    exit action x:=0; end exit;
  end State1;
  State1 state1 annotation(extent=[-66,62; -41,48]);
  State A3 annotation(extent=...);
  State I5(isInitial=true)...;
  State F7(isFinal=true)...;
  transition I5->state1 end transition
      annotation(points=[-76,73;-64,71; -64,62]);
  transition l1:state1->A3 event on action x:= 2.0;
  end transition annotation(points=...);
  transition l2:A3->state1 event off guard y < 5
      action x:=3.0;
  end transition annotation ...;
  transition state1->F7 end transition annotation...;
 end A1SC;
end A1;
```

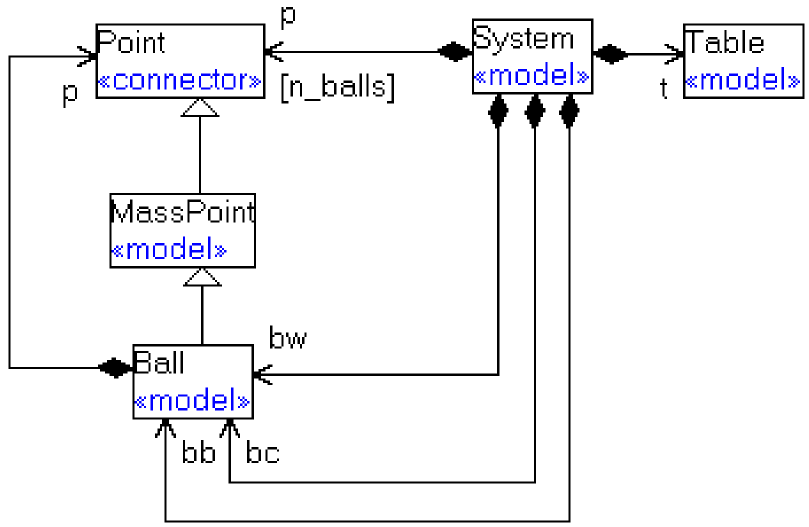
Modelica code

Example for UML^{H}-modelling: Model of a Pool-Billiard game (1)

Model assumptions

1. The Pool-Billiard game knows only a black (bb), a white (bw) and a coloured ball (bc).
2. The table (t) has only one hole instead of 6 holes.
3. The collision-model is strong simplified.
4. The balls are moving between the collisions and reflections only on straight directions in the dimension x and y.
5. The reflections on the borders take place ideal without any friction losses.
6. The rolling balls are slowed down with a linear friction coefficient f_r:

$$m \cdot \frac{dv_x}{dt} = -v_x \cdot f_r \qquad m \cdot \frac{dv_y}{dt} = -v_y \cdot f_r$$

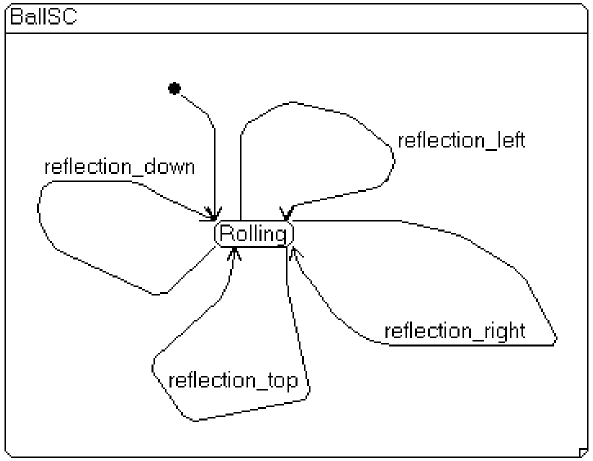


UML^{H}-class diagram for the ball model

Example for UML^H-modelling: Model of a Pool-Billiard game (2)

Model events on the ball model-level:

1. Reflection on the left border (reflection_left)
2. Reflection on the top border (reflection_top)
3. Reflection on the right border (reflection_right)
4. Reflection on the lower border (reflection_down)



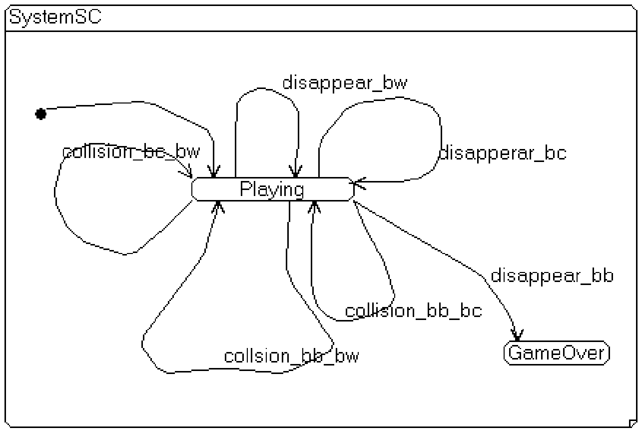
UML^H-Statechart diagram for the ball model

```
model Ball
  extends MassPoint(m=0.2);
  parameter SIunits.Length width, length;
  parameter SIunits.Length d = 0.0572 "diameter";
  parameter Real f_r = 0.1 “friction coefficient”;
  SIunits.Velocity v_x, v_y;
  event Boolean reflection_left(start = false);
  ...
equation
  reflection_left = if x < d/2.0;
  m * der(v_x)  = - v_x * f_r; der(x) = v_x;
  ...
statechart
  state BallSC extends State;
    State Rolling;
      State startState(isInitial=true);
    transition startState -> Rolling end transition;
    ...
    transition Rolling->Rolling event reflection_left
      action v_x := -v_x; x := d/2.0;
    end transition;
  end BallSC;
end Ball;
```

Example for UML^H-modelling: Model of a Pool-Billiard game (3)

Model events on the system model-level

1. Collision of two balls
   - bb / bc; bb / bw; bw / bc
2. Disappearance of a ball in the hole
   - bb, bw and bc



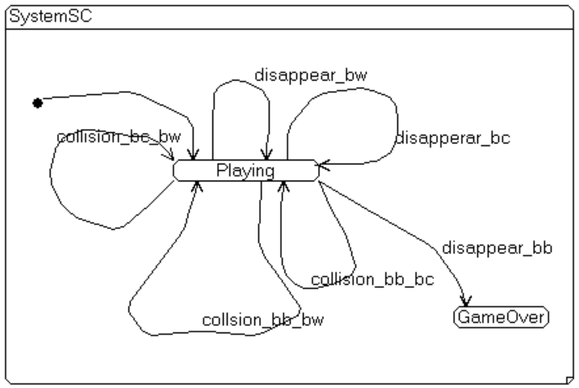
UML^H-Statechart diagram for the system model

```
model System
  parameter SIunits.Length d_balls = 0.0572;
  parameter SIunits.Length d_holes = 0.15;
  dynamic Ball bw, bb, bc; //structural dynamic submodels
  Table t(width = 1.27, length = 2.54);
  event Boolean disappear_bw(start = false);
  event Boolean disappear_bb(start = false);
  event Boolean disappear_bc(start = false);
  event Boolean collision_bw_bb(start = false);
  ...
  event Boolean push(start = false);

equation
  push = if fabs(bw.v_x)<0.005 and fabs(bw.v_y) < 0.005;

  disappear_bw = if((p[1].x-0)^2+(p[1].y-0)^2)^0.5 < d_holes;

  collision_bw_bb = if((p[2].x-p[1].x)^2
                  +(p[2].y-p[1].y)^2)^0.5 < d_balls;
```

Example for UML^H-modelling: Model of a Pool-Billiard game (4)

Model transition on the system model-level

1. **Initial transition**
   initialization of the balls and their positions
2. **Playing → Playing**
   triggered by collision or disappearance events
3. **Playing → GameOver**
   triggered by the disappearance event of bb



UML^H-Statechart diagram for the system model

```
statechart
  state SystemSC extends State;
  State Playing, startState(isInitial=true), GameOver;     ...
  transition startState -> Playing action
    bw := new Ball(d = d_balls,...); add(bw);
    bb := new Ball(...); add(bb);
    bc := new Ball(...); add(bc);
  end transition;
  transition Playing->Playing event disappear_bw action
    ... remove(bw);
    bw := new Ball(x(start=1.27/2.9), y(start=0.6));
  end transition;
  transition Playing->Playing event disappear_bc action
    ... remove(bb);
  end transition;
  transition Playing -> GameOver event disappear_bb
  end transition;
  transition Playing->Playing event collision_bw_bb action
    v_x := bw.v_x; v_y := bw.v_y;
    bw.v_x := bb.v_x; bw.v_y := bb.v_y;
    bb.v_x := v_x; bb.v_y := v_y;
  end transition;
end SystemSC;
...
```

Example for UML^H-modelling: Simulation experiment (1)

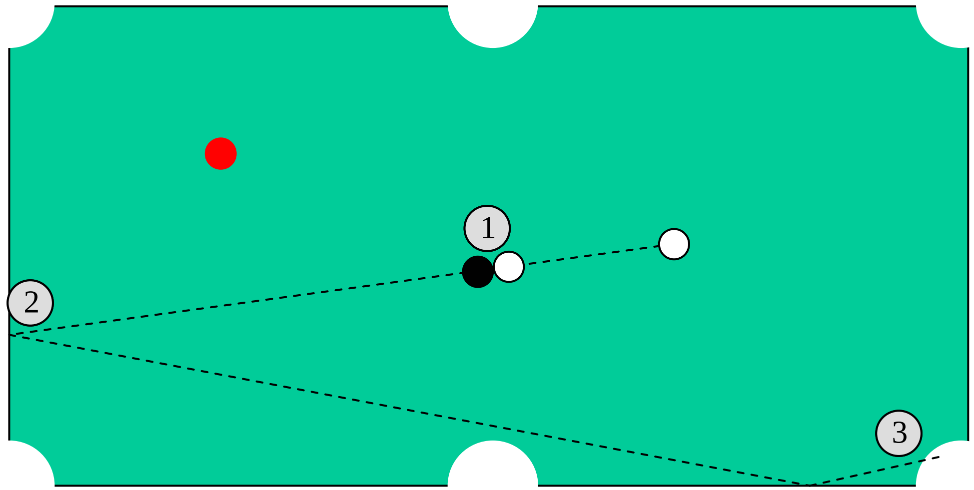
– **Simulation experiment**

- Duration: 4 seconds
- Event sequence:

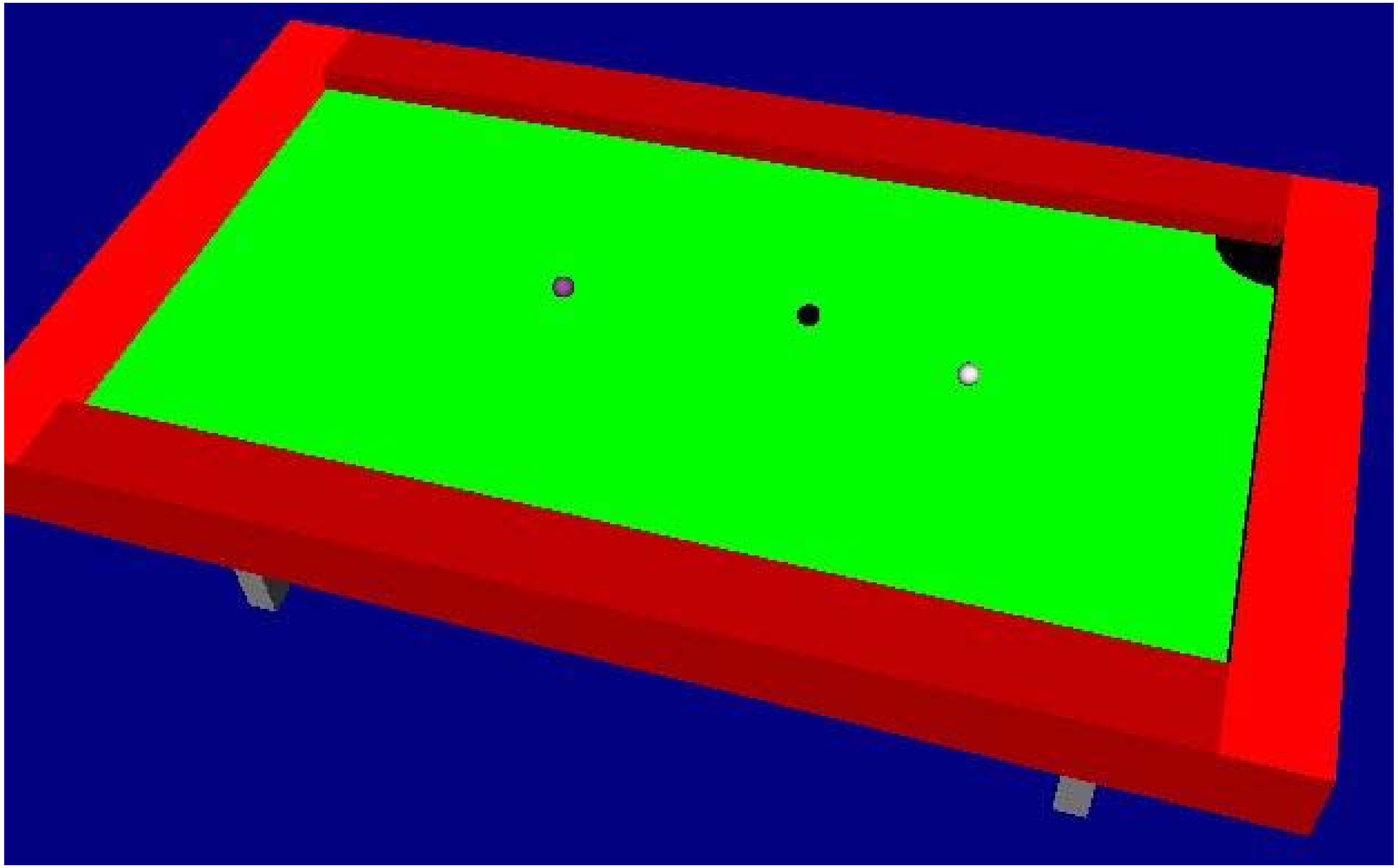
① bw hits on bb

② bb reflects on the left and the lower border

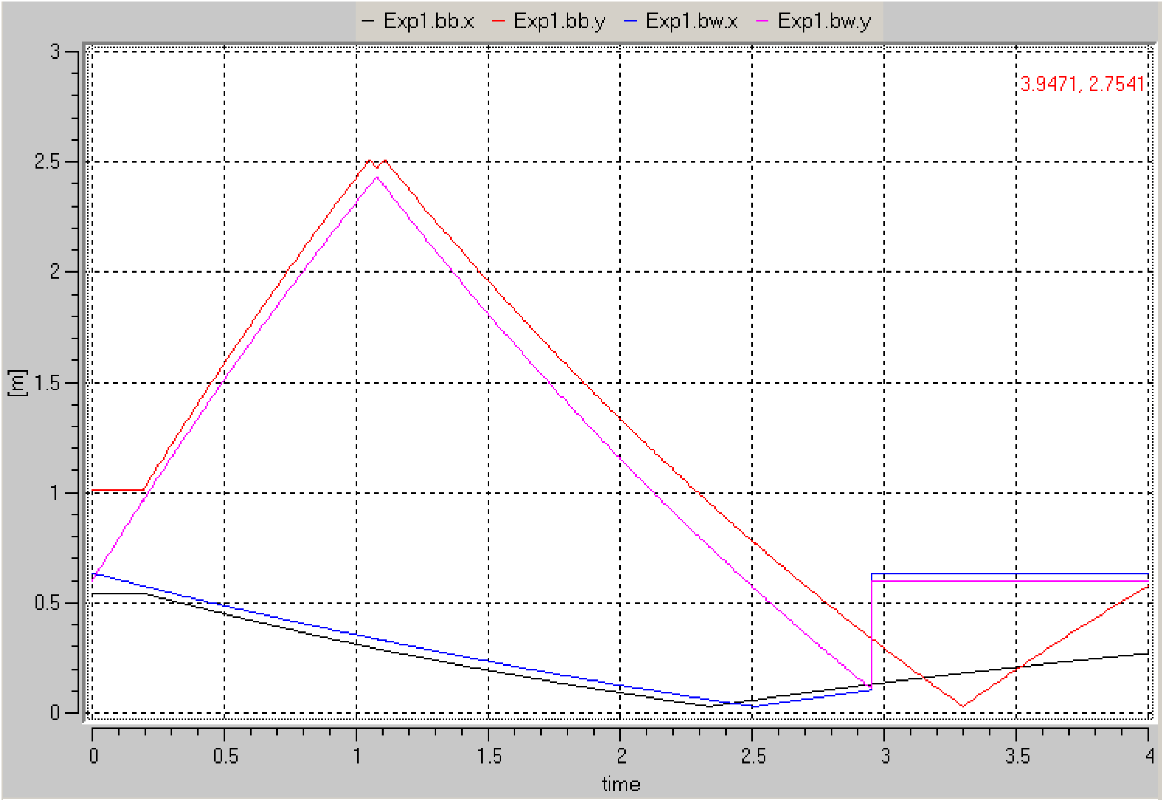
③ wb disappears in the hole



Example for UML^{H}-modelling: Simulation experiment (2)

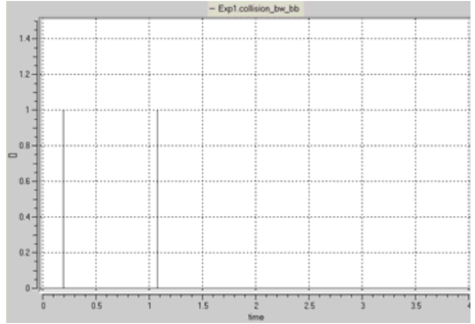


Example for UML^H-modelling: Simulation experiment (2)

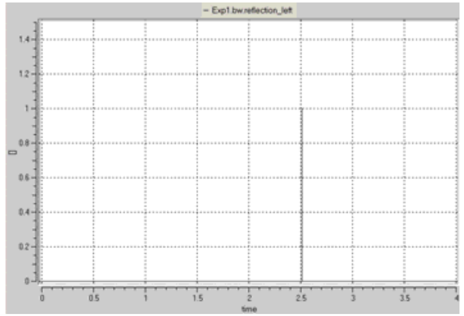


x- and y-positions of the white and the black ball

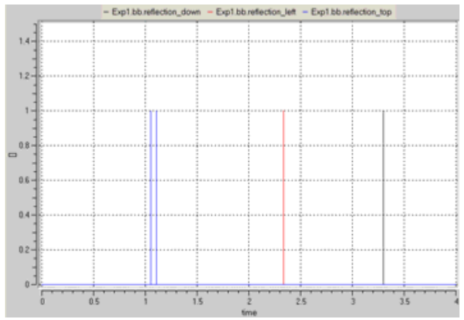
Collision events:
white and
black ball



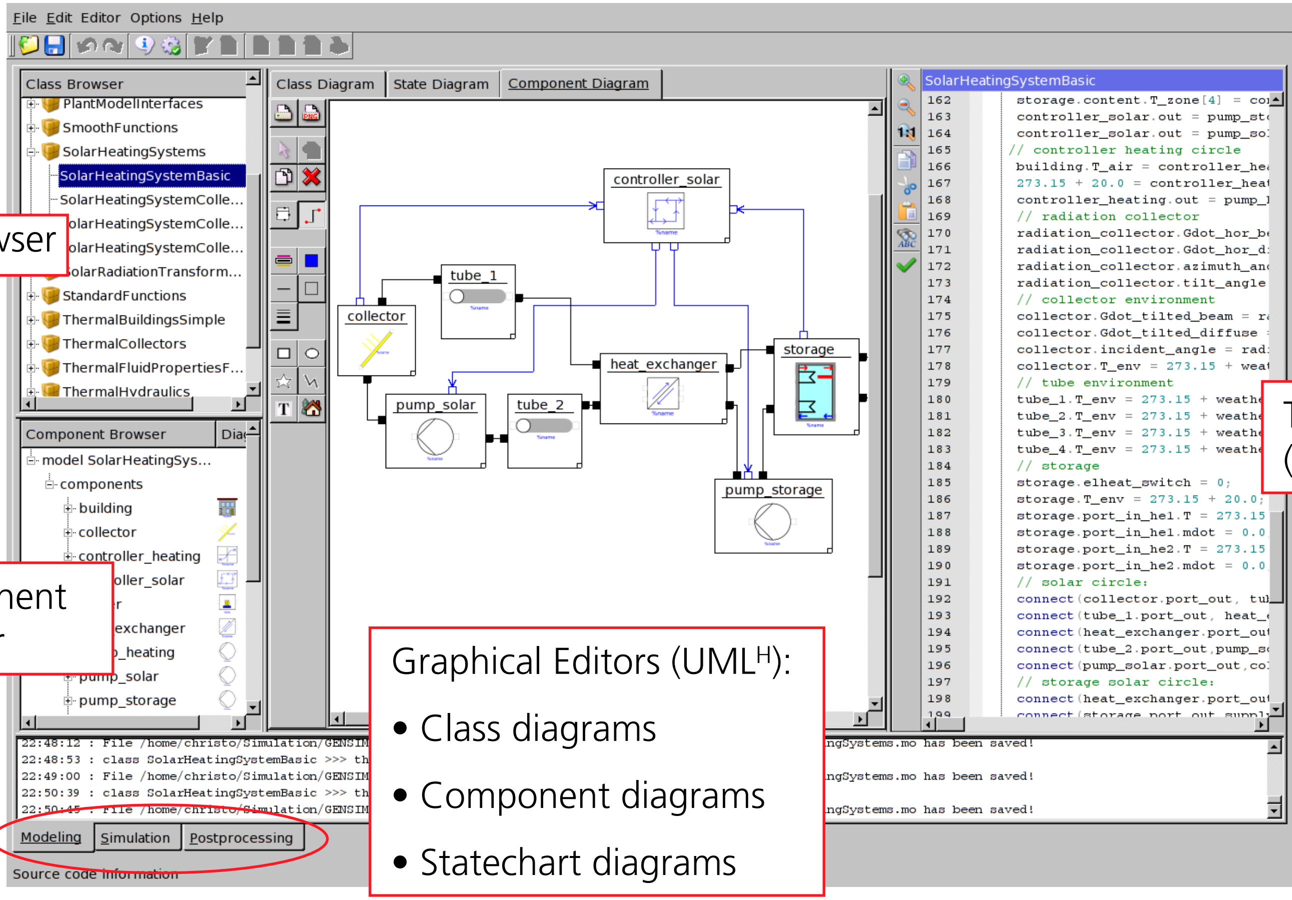
Reflection events:
white ball



Reflection events:
black ball



MOSILAB-IDE for model based development (GENSIM-Project)



Class Browser

Component Browser

Development Workflow

Text Editor (Modelica)

Graphical Editors (UML^{H}):

- Class diagrams
- Component diagrams
- Statechart diagrams

Summary

- UML^H offers three model views on OO-Modelica-models
- The modelling example of the Pool-Billiard game demonstrates the advantages of UML^H-modelling
- The Modelica-tool MOSILAB supports code generation starting from UML^H-models