HYVISUAL: A HYBRID SYSTEM MODELING FRAMEWORK BASED ON PTOLEMY II [*]

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Extended Abstract *Copyright © 2006 IFAC*

HyVisual is a hybrid systems modeling framework providing a block diagram visual syntax for specifying continuous dynamics and a bubble-and-arc syntax for specifying modal behavior. It is based on Ptolemy II, is written in Java, and is distributed open-source at http://ptolemy.eecs.berkeley.edu/hyvisual/.

HyVisual has a rigorous operational semantics described in Lee and Zheng (2005). A key property is that it internally uses *superdense time*, where signals are modeled as partial functions of the form $f\colon \mathbb{R}_+ \times \mathbb{N} \rightharpoonup V$, where $\mathbb{R}_+$ is the non-negative real numbers and represents time, V is the value set (a data type, such as $\mathbb{R}^n$), and $\mathbb{N}$ is the set of natural numbers. Continuous-time functions are total, whereas discrete-event functions are defined only on a discrete subset of $\mathbb{R}_+$. The $\mathbb{N}$ in the domain permits signals to have multiple values in a well-defined order at a particular time. Using this framework, HyVisual gives a rigorous semantics to discontinuous signals (which have multiple values at the point of discontinuity), to discrete-event signals with multiple events at the same time, and to transient states, where the time spent in the state is zero.

An example of a HyVisual model that leverages this is shown in fig. 1, which shows many features of HyVisual. This models Newton's cradle, an apparatus with three (or more) balls hanging from strings (inspired by a one dimensional version in Mosterman (1999)). If the model is initialized with one of the balls displaced as shown in the HyVisual graphical animation at the lower left, then when the ball collides with the middle ball, a transient state results. At that time, the right ball transfers its momentum to the middle ball, and then, without any time elapsing, the middle ball transfers its momentum to the left ball. The two events (state transitions in the state machine at the middle left) are simultaneous but ordered. Other initial conditions can be chosen where two simultaneous events are unordered (e.g., starting with two balls appropriately displaced). HyVisual allows a model to permit nondeterministic choice of enabled transitions.

REFERENCES

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CT Director

- acceleration: 9.8
- length: 8.0
- diameter: 2.0
- initialTheta_1: -PI/8
- initialTheta_1_dot: 0.0
- initialTheta_2: 0.0
- initialTheta_2_dot: 0.0
- initialTheta_3: 0.0
- initialTheta_3_dot: 0.0

This hybrid system models an apparatus called Newton's cradle with 3 identical balls suspended by strings. Each ball can swing as a pendulum. Its dynamic behavior is modeled in the BallClass class definition.

The parameters on the left specify the sizes of the balls and their initial states. The initial states include the initial angle away from the equilibrium position (initialTheta) and initial velocity (initialTheta_dot). In this example, the first ball starts at an angle of PI/8.

positions

velocities   ModalModel   positions

theta_1_dot   x_1
theta_2_dot   x_2
theta_3_dot   x_3

BallClass

initialTheta   x
initialTheta_dot   y
theta
theta_dot

PeriodicSampler   Graphic Animation

A model with three balls, each of which is an instance of the BallClass class.

ball1
initialTheta   x
initialTheta_dot   y
theta
theta_dot

x_1
theta_1
theta_1_dot

ball2
initialTheta   x
initialTheta_dot   y
theta
theta_dot

x_2
theta_2
theta_2_dot

ball3
initialTheta   x
initialTheta_dot   y
theta
theta_dot

x_3
theta_3
theta_3_dot

The transition from the init state to the run state initializes the positions and velocities of the balls. A transition is taken from the run state back to itself when a collision occurs. A collision occurs when two adjacent balls make contact with velocity greater than zero. The collision is perfectly elastic, so since the two balls have the same mass, they simply exchange their velocities.

true

state.theta_1_dot_initial = initialTheta_1_dot;
state.theta_2_dot_initial = initialTheta_2_dot;
state.theta_3_dot_initial = initialTheta_3_dot;
state.theta_1_initial = initialTheta_1;
state.theta_2_initial = initialTheta_2;
state.theta_3_initial = initialTheta_3

init

run

((x_2 + diameter) >= x_3)
 && (theta_2_dot > theta_3_dot)

state.theta_2_dot_initial = theta_3_dot;
state.theta_3_dot_initial = theta_2_dot

((x_1 + diameter) >= x_2)
 && (theta_1_dot > theta_2_dot)

state.theta_1_dot_initial = theta_2_dot;
state.theta_2_dot_initial = theta_1_dot

This class defines the dynamics of a pendulum.

- acceleration: acceleration
- length: length
- x_offset: 0.0
- y_offset: 0.0

Const   PolarToCartesian   y position   y

length   in + y_offset

angle   x position   x

in + x_offset

theta_dot   theta   Expression

-1*sin(theta)*acceleration/length

initialTheta: 0.0   theta_dot   theta
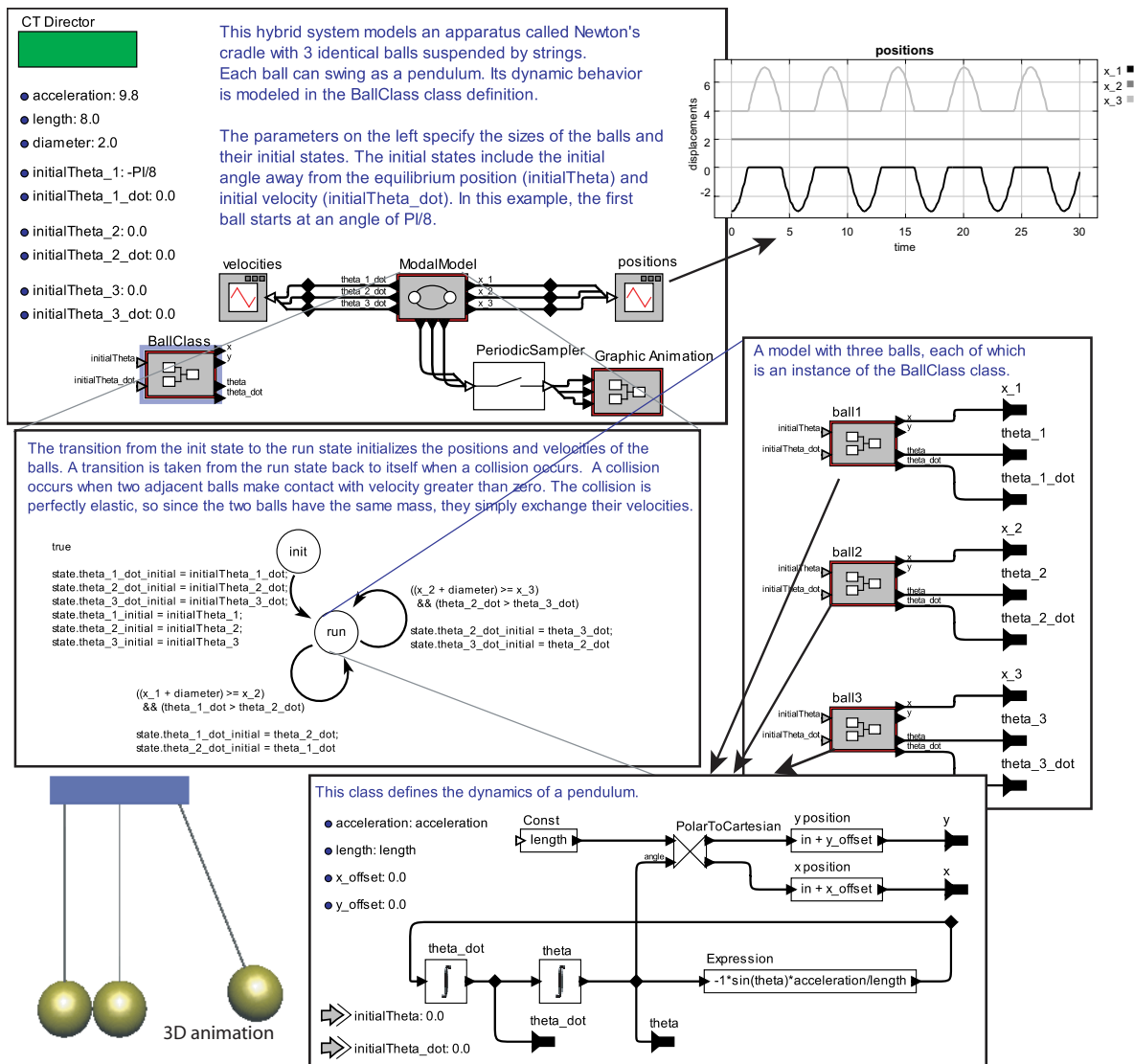
initialTheta_dot: 0.0

3D animation

Fig. 1. The Newton's cradle example illustrates many features of HyVisual.