



C7 Constrained Pendulum – AnyLogic

Hybrid approach

Simulator: AnyLogic 4.0 is able to handle continuous, discrete and hybrid models. It is based on JAVA and offers some drag-and-drop dialogues for the model as well as for animation. Everything needed is created as an instance of the ActiveObject class, starting with the 'Root' class which represents the model to variables, statecharts and animation.

Model: Using tangential velocity $v = l \cdot \dot{\varphi}$ instead of angular velocity has the advantage that only the length has discrete changes. The equation of the model transforms to

$$\dot{\varphi} = v/l, \quad v = -g \cdot \sin \varphi - \frac{d}{m} v$$

$$v = l_1 \cdot \dot{\varphi}_1 = l_s \dot{\varphi}_s$$

Using ActiveObjects for $v=x1$, $\varphi=x2$, it boils down to the equations

$$d(x1)/dt=1/laenge*x2$$

$$d(x2)/dt=-grav*\sin(x1)-dae/mass*x2$$

in the equations section of the main object, and a statechart to determine the initial state and the state changes, the length being changed in the transitions.

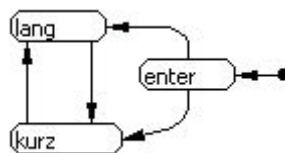


Fig.1: Statechart of the model

Task a: Simulation in the time domain: The runtime engine included in AnyLogic offers convenient routines for plotting variables defined as active objects. Simulating both at once is easily done by creating two instances of the ActiveObject pendulum with different initial values (Fig 2).

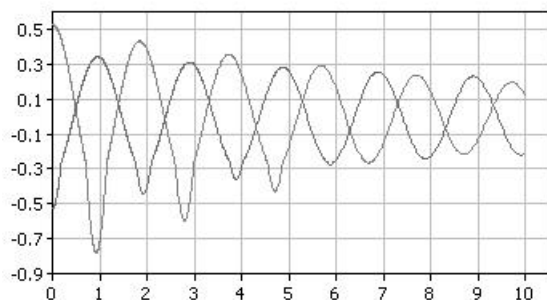


Fig. 2: Angle and Angle Velocity, task a

Task b: Comparison of linear and nonlinear model. The creation of an almost identical ActiveObject for the linearised constrained pendulum with the equations

$$d(x1)/dt=1/laenge*x2$$

$$d(x2)/dt=-grav*x1-dae/mass*x2$$

allows the comparison of both models. Placing instances of both types in the 'Root' class as shown in the image allows for a direct comparison in the runtime environment, as a runtime plot forces the numerical integration to use at most the same stepsize.

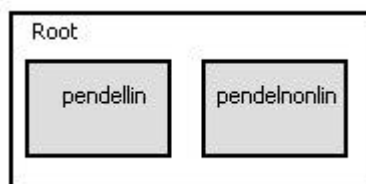


Fig.3: both models as ActiveObjects in the „Root“ ActivObject

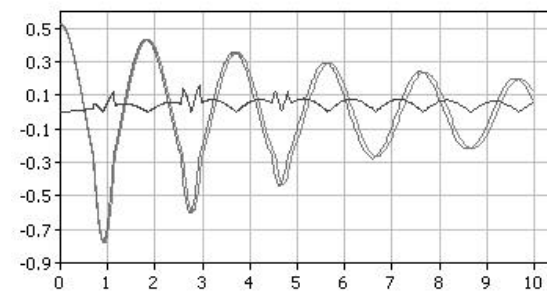


Fig.4: Comparison of linear and nonlinear model (angle, difference)

Task c: Boundary value problem With the simple transformation $\tau = -t$ we reverse the system time. We start with the maximum angle and a tangential velocity of 0. By adding a final state to statechart the calculation can be stopped once the given initial angle is reached. Thus at time $t=0.5750$ the simulation finishes with a tangential velocity $x2=2.0756$, which equals the angular velocity, as the length of the pendulum in its long state is 1.

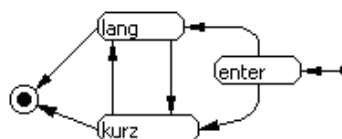


Fig. 5: Model state chart with final state

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