A System Dynamics Approach to ARGESIM Comparison C7 'Constrained Pendulum' with Vensim

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Simulator: Vensim is used for developing, analyzing, and packaging high quality dynamic feedback models. Models are constructed graphically or in a text editor. Vensim is based on the ideas of System Dynamics, so also qualitative modelling with causal diagrams is possible. Features include dynamic functions, subscripting (arrays), Monte Carlo sensitivity analysis, optimization, data handling, application interfaces.

Model description: The model is implemented using standard Vensim Blocks (Figure 1). Vensim PLE (free educational version) only supports Euler and RK4 integration algorithms. (RK4 is used in this solution; the professional Vensim version offers also better algorithms with stepsize control, etc.) Vensim does not support state event handling. Instead, the "IF THEN ELSE" command is used to change the length of the pendulum. To get good results, small timesteps have to be used. To avoid problems with discontinuous changes of integration variables, we use the variables instead of the angle velocity the tangential velocity, which does not change during the hit.

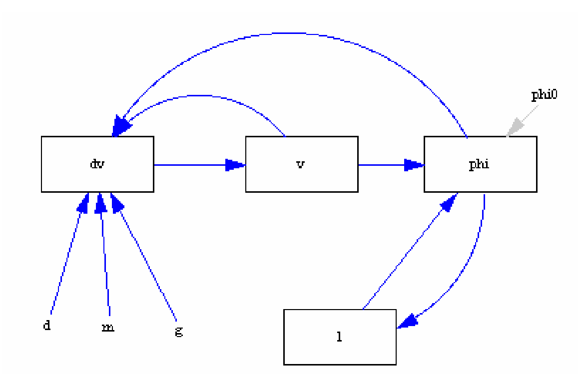

Figure 1: Vensim model in SD-like block notation

Task a: Simulation with different parameters. Vensim has some nice features that help experimenting with model parameters. It allows changing parameter values with a slider bar and automatically updates the graphs of all variables. Another nice feature is the temporarily change of parameters by means of `set up a simulation` menu. A standard feature is storing and reloading results from simulation runs, so that, results for task a can easily displayed within one graph (Figure 2).

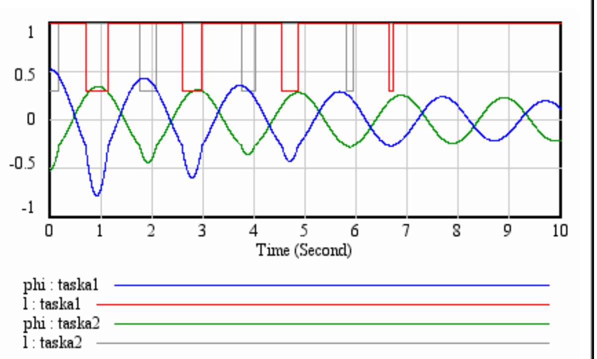

Figure 2: Angle, angle velocity and pendulum length for different parameters

Task b: Comparison of nonlinear and linear model. However, it is not possible to apply any function to the data, e.g. it is not possible to calculate e.g. differences between stored data (in this case the deviation of angles of nonlinear and linear model. For this reason, the linearised and the nonlinear model had to be modelled together in order to compute the difference at model level (results in Figure 3).

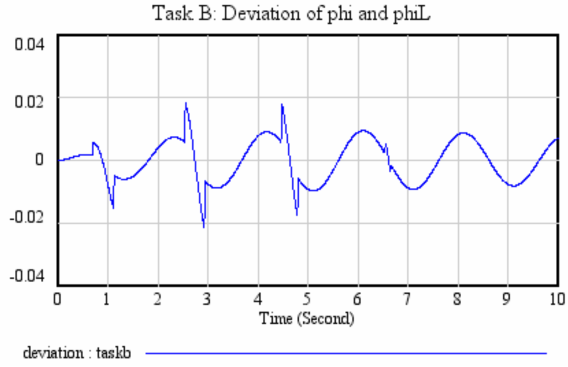

Figure 3: Difference of angles in linear and nonlinear model

Task c: Boundary value problem. The boundary value problem can be avoided by a time transformation. Reversing the time only changes the sign of the damping constant d. Therefore, the problem can be redefined as follows: The pendulum is released at position $-\pi/2$, with initial velocity zero. The damping constant is negative. The velocity of the pendulum when it is passing $\pi/6$ is to be calculated. In order to get this value, among the stored data for angle and angle velocity the values are interpolated around angle $\pi/6$. This results in a value of 2.18355 m/s.

C7 Classification: Approach without state events

Simulator: Vensim PLE 5.1