

Modeling ARGESIM Benchmark ‘C13 Crane and Embedded Control’ with Hybrid System Approach using Scicos

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Simulator: Scilab (www.scilab.org) is a free and open source simulation environment used for scientific computing. Scicos (www.scicos.org) is a toolbox of Scilab used for modeling and simulation of very general hybrid systems [1]. Scilab/Scicos can be considered as the counterparts of Matlab/Simulink. In Scicos which is a block diagram oriented simulator both discrete-time and continuous-time systems or in general hybrid systems can be modeled and simulated. Scicos has several toolboxes for predefined blocks and the user can define new blocks. Scicos has been extended to support a subset of Modelica language to define the behavior of blocks and the simulate component based models.

Model: The Modelica language provides the possibility of writing the nonlinear model directly as DAE. Thus we have used a generic Modelica block to build a block modeling the nonlinear car including the motor and the brake, see Fig. 1, 2. The inputs of the nonlinear model are fc_{des} (Desired force), fd (disturbance forces), and $BrakeStatus$. The outputs are xc , a and xL . The Modelica compiler of Scicos then compiles the program and generates a C code which can be integrated by the numerical solver. The Modelica program used used in the block follows.

```

1 class Nonlinear
2 ...
3 equation
4   DC=if (BrakeStatus>0.5) then dc
       else dc_Brake;
5   der(fc)=-4*(fc-fc_des);
6   Sa=Modelica.Math.sin(a);
7   Ca=Modelica.Math.cos(a);
8   der(xc)=w;
9   der(w)*(mc+ml*Sa^2.0)=
       -DC*w+fc+fd*Sa^2.0+...;
10  der(a)=da;
11  r*r*der(da)*(ml*Sa^2+mc)=
       (fd*mc/ml-fc+DC*w)*...;
12  xL=xc+r*Sa;
13 end Nonlinear;

```

In Scicos, the user is allowed to use standard Scicos blocks and Modelica blocks in the same diagram. Thus the rest of the model, *i.e.*, the controller, input signals, the display mechanism, the car supervisor which operates concurrently with the car controller

have been implemented with standard Scicos blocks

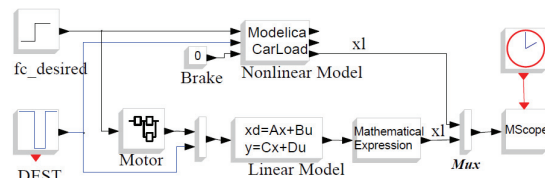


Figure 1. Scicos Model for A-task

such as event sources, discrete linear systems, counters, logic gates, comparators, see Fig. 3.

Scicos is inherently an event based simulator. At every discrete event time instant discrete parts of the model are updated. Between two discrete events only continuous parts (here the DAE and linear parts) are integrated. Each time there is discontinuity in input signals or in the continuous part and at sampling time instants, the Scicos simulator cold-restarts the numerical solver [2].

A-Task: The linear system including the discrete observer, the controller, and the motor has been implemented directly with Scicos standard blocks, whereas the nonlinear part, as aforesaid, is implemented with Modelica, see Fig. 1.

In order to compute the steady state values, a Scilab program calls the Scicos diagram of Fig.1 in batch mode with different values of disturbances. The steady state errors in x_L after 2000 seconds are given in table 1.

```

1 load Task1.cos;
2 dest=[-750,-800,-850];
3 for i=1:3
4   Info=list();
5   %scicos_context.DEST=dest(i);
6   Info=scicos_simulate(scs_m,Info,
       %scicos_context,'nw');
7   Y=Info(2).state.outtb(10);
8   diff(i)=Y(1)-Y(2);
9 end

```

B-Task: The complete model of the car, controller, input signals, etc. are given in Fig.2. The supervisor including the brake condition checking is shown in Fig. 3. At each sampling time instant, if the desired force is less than the brake condition, the counter is incremented by one. Whenever the counter

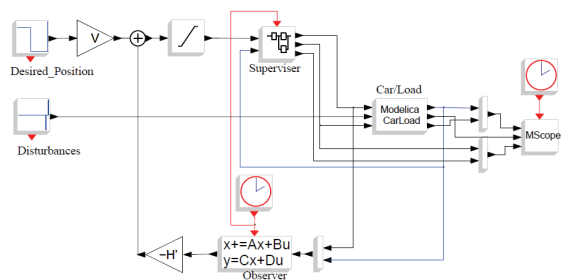


Figure 2. Scicos diagram used for B-task and C-task

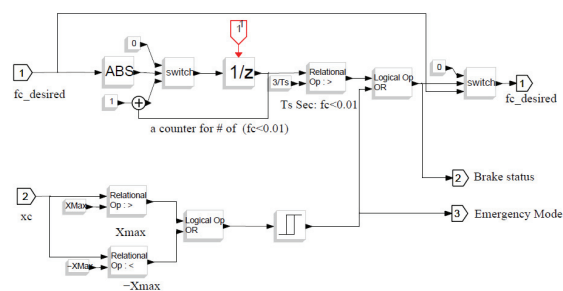


Figure 3. Supervisor block used in diagram of Fig. 2

reaches $3/T_s$, the brake status is activated, which in turn causes a change in the friction coefficient in the Modelica model of the car. Fig.4a shows the result for the car and load positions (x_C, x_L), Angle (α), and the brake status. The brake is active at $t = 35.5$ for about 0.5 seconds.

C-Task: The diagnostic mechanism has been implemented with two comparison blocks and a OR block, as shown in Fig. 3. Whenever x_C becomes less than x_{min} or greater than x_{max} , the OR blocks becomes active and change the outputs of the hysteresis block. The output of the hysteresis block remains high, regardless of the input state. This mechanism can also be implemented easily within the Modelica program. Fig. 4b shows the results for the car and load positions (x_C, x_L), Angle (α), and the brake status and the emergency stop. The car does an emergency stop at $t=47.94$ Sec.

Although it is possible to implement all supervisor mechanism with Modelica, we decided to use stan-

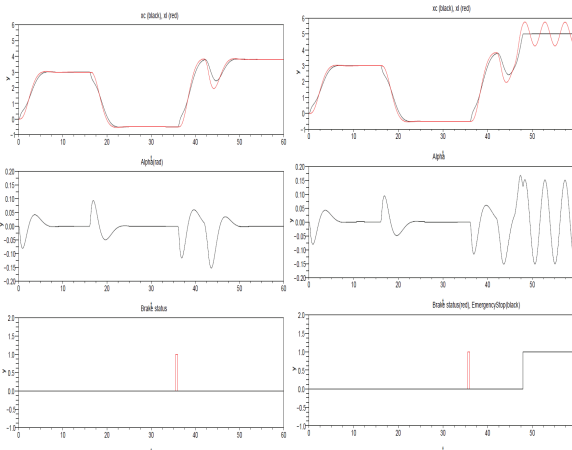


Figure 4. Simulation result for (a) B task, (b) C task

standard Scicos blocks. The main reason lies in the fact that unfortunately a Modelica program cannot be synchronized with an external event sources. An implementing the counter in the Modelica program requires using an additional event source which doubles the number of the solver cold re-starts and reduces the simulation speed.

Résumé: The proposed solution uses different modeling methods available in Scicos. The linear continuous time blocks are modeled with blocks in the linear palette of Scicos, the discrete time observer is implemented using a periodic event source and a linear discrete system, and the nonlinear part has been implemented using the Modelica language. All these parts give a nonlinear hybrid DAE system of equation which can be simulated by the Scicos simulator.

References

[1] S. L. Campell, J. Chancelier, R. Nikoukhah. *Modeling and simulation in Scilab/Scicos*. Springer, 2005.
 [2] M. Najafi. *The Numerical Solver for the Simulation of the Hybrid Dynamical Systems*. Doctor of science thesis, Paris XII University, 2005.

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Received: September 10, 2007
 Accepted: September 20, 2007

Dest	Δx_L (non-linear to linear)
-750	-0.000307
-800	0.004533
-850	0.000919

Table 1: Steady state errors in x_L after 2000 seconds