Analyzing Numeric Integration in Dymola

Writing good models is more difficult in practice than in theory. A model must not only be accurate (within its scope of definition and level of abstraction), it should preferably also lend itself to efficient simulation.

In some cases bad numeric behavior may indicate a more serious modeling problem or an unexpected interaction between subsystems.

Dymola 2018 has been enhanced with support to analyze the interaction between models and the numeric integration, helping the user to improve models for more efficient simulation and to tune the numeric integration to match the needs of the model.

Introduction

Dymola 2018 offers two complementary approaches for analyzing the model simulation properties.

► From a model perspective, analyze state variables and how each influences the solution error and the numeric integration.

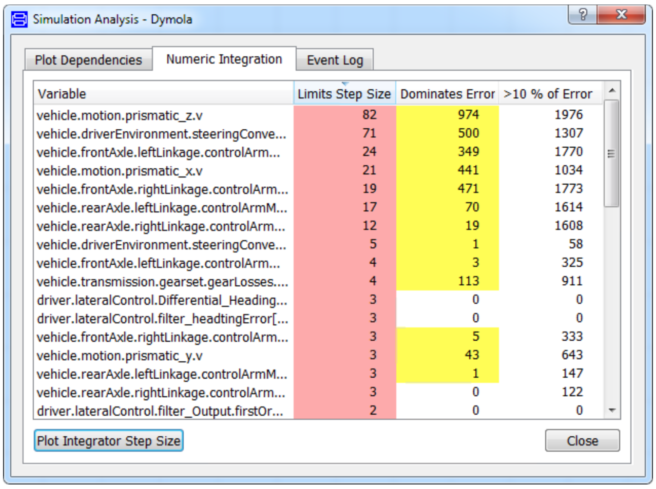
► From a global perspective, analyze the step size and order of a variable step-size integration algorithm.

For both the first action is to turn on statistics gathering by enabling “Which state that dominate error” in Simulation>Setup…>Debug.

Running an example

We have picked a vehicle suspension example, driving on a sloped and curved section of road that demonstrates the roll and pitching motions of the vehicle when going over a surface with a varying normal. Initially the model was simulated with the default integration algorithm DASSL.

After simulation detailed information is available by right-clicking on the simulation result in the variable browser and selecting **Analyze Numerics** from the context menu.



Variable	Limits Step Size	Dominates Error	>10 % of Error
vehicle.motion.prismatic_z.v	82	974	1976
vehicle.driverEnvironment.steeringConve...	71	500	1307
vehicle.frontAxle.leftLinkage.controlArm...	24	349	1770
vehicle.motion.prismatic_x.v	21	441	1034
vehicle.frontAxle.rightLinkage.controlArm...	19	471	1773
vehicle.rearAxle.leftLinkage.controlArmM...	17	70	1614
vehicle.rearAxle.rightLinkage.controlArm...	12	19	1608
vehicle.driverEnvironment.steeringConve...	5	1	58
vehicle.frontAxle.leftLinkage.controlArm...	4	3	325
vehicle.transmission.gearset.gearLosses....	4	113	911
driver.lateralControl.Differential_Heading...	3	0	0
driver.lateralControl.filter_headtingError[...	3	0	0
vehicle.frontAxle.rightLinkage.controlArm...	3	5	333
vehicle.motion.prismatic_y.v	3	43	643
vehicle.rearAxle.leftLinkage.controlArmM...	3	1	147
vehicle.rearAxle.rightLinkage.controlArm...	3	0	122
driver.lateralControl.filter_Output.firstOr...	2	0	0

The window that opens shows the following information for each state variable; it can be sorted in ascending or descending order by clicking on any of the column headings.

► The number of times the variable limits the step size of the numerical integrator. Counts greater than zero are highlighted.

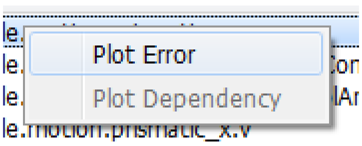
► The number of times the variable dominates the error, i.e. has an integration error larger than any other state variable. Counts greater than zero are highlighted.

► The number of times the variable’s error is more than 10 % of the integration error.

Analyzing states

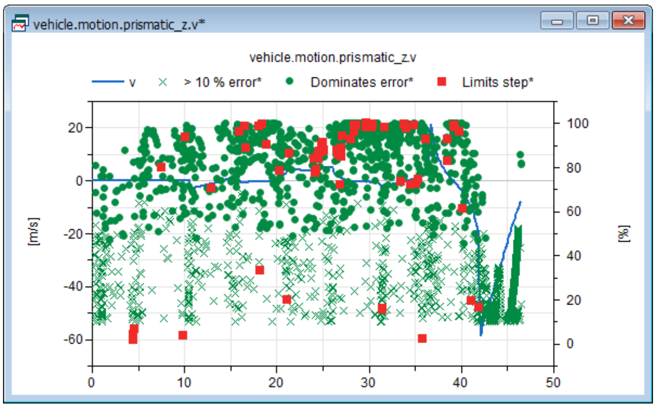
We can inspect state variables that most likely slow down the simulation of the model. A good starting point is to focus on states that limit the step size, followed by any states that unexpectedly dominate the error.

Right-click on a variable displays a context menu with two commands.



Plot Error creates a new plot window and displays the time-plot for the variable, as well as the information regarding limits step size, dominates error and more than 10 % of error.

In the plot a marker is plotted at each time point where this occurs, and the value on the right vertical axis is the fraction of the total integration error in percent. This plot facilitates a better understanding of the variable's effect on the numeric integrator at various stages of the simulation.

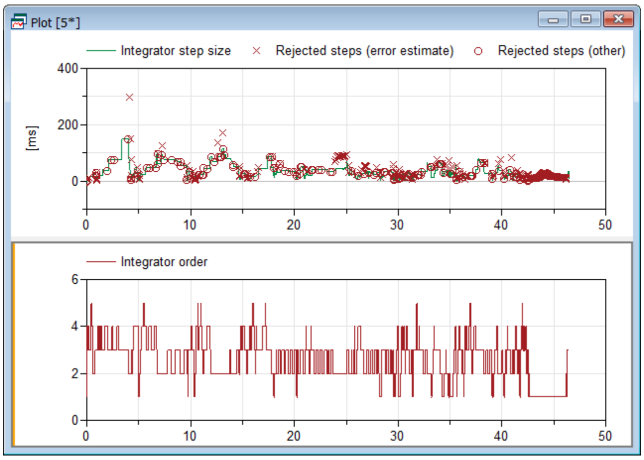


Plot Dependency displays the dependencies of the variable in a new window, and will not be further discussed here.

Integrator step and order

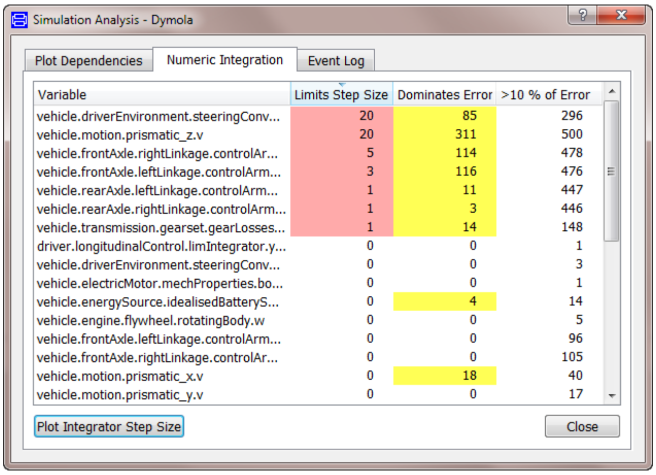
The overall behavior of the numeric integrator can be studied by pressing the **Plot Integrator Step Size** button, which opens a new plot window showing the internal integrator step size, rejected steps, and in a separate plot the integrator order.

We can see that the integrator (DASSL, the default) is using short steps around 100 ms, has a high number of rejected steps, and an irregular integrator order pattern.



Selecting a better integration algorithm

The above analysis suggests that for example ESDIRK45A would be a more appropriate integration algorithm, and re-running the simulation shows significantly reduced numbers.



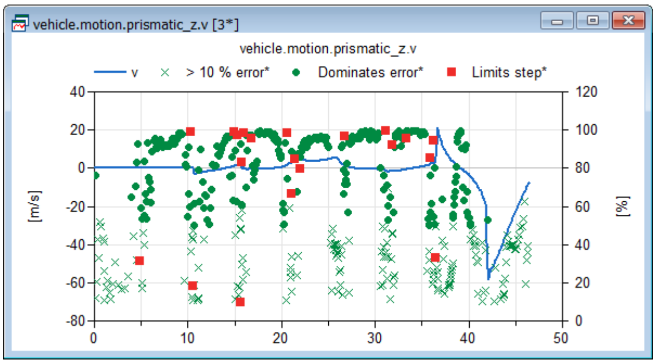
Simulation Analysis - Dymola

Plot Dependencies | Numeric Integration | Event Log

Variable	Limits Step Size	Dominates Error	>10 % of Error
vehicle.driverEnvironment.steeringConv...	20	85	296
vehicle.motion.prismatic_z.v	20	311	500
vehicle.frontAxle.rightLinkage.controlAr...	5	114	478
vehicle.frontAxle.leftLinkage.controlArm...	3	116	476
vehicle.rearAxle.leftLinkage.controlArm...	1	11	447
vehicle.rearAxle.rightLinkage.controlArm...	1	3	446
vehicle.transmission.gearset.gearLosses...	1	14	148
driver.longitudinalControl.limIntegrator.y...	0	0	1
vehicle.driverEnvironment.steeringConv...	0	0	3
vehicle.electricMotor.mechProperties.bo...	0	0	1
vehicle.energySource.idealisedBatteryS...	0	4	14
vehicle.engine.flywheel.rotatingBody.w	0	0	5
vehicle.frontAxle.leftLinkage.controlArm...	0	0	96
vehicle.frontAxle.rightLinkage.controlAr...	0	0	105
vehicle.motion.prismatic_x.v	0	18	40
vehicle.motion.prismatic_y.v	0	0	17

Plot Integrator Step Size
Close

Inspection of the previously major limiting state shows a marked improvement.



It is further confirmed by a plot of the integrator step, although a number of rejected steps are still present. We also noted that the execution time is much better.

Conclusion

Dymola 2018 has been enhanced with powerful tools that help the understanding of the numerical properties of a model. They allow us to find hotspots in the model, potential errors, or simply to select an appropriate integration algorithm.