universal mechanism

Getting started

UM Automotive

2024

Contents

Getting Started Using Universal Mechanism: simulation of car dynamics

This manual leads you through basics of describing the models, running and analyzing results of car dynamics using Universal Mechanism software. It assumes that you studied the **gs_UM.pdf**[1] chapter, which is devoted to general concepts of simulation using Universal Mechanism, and you know how to fulfill simple operations: create new model, add graphical objects, bodies and joints, generate and compile equations of motion.

We will consider simulation of dynamics of a model of VAZ 2109 (LADA).

It assumes that you go through the manual step by step sequentially. Information that is given in one section might be further given shortly or even omit.

[1] www.universalmechanism.com/download/90/eng/gs_um.pdf

Compatibility

Simulation of car dynamics is supported by **UM Automotive** module. Before coming to the rest part of the manual please check if **UM Automotive** is available on your computer. Run **UM Input** or **UM Simulation** and from the **Help** menu select **About**…. The list of available modules is shown in the **Configuration** section.

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Contact information

The latest UM version as well as up-to-date UM user's manual available at http://www.universalmechanism.com/en/pages/index.php?id=3.

Please, send your bug reports, questions and suggestions to um@universalmechanism.com.

Phone, fax: +7 4832 568637.

1. Simulation of dynamics of VAZ 2109

A model of VAZ 2109 car is situated in the {UM Data}\ SAMPLES\automotive\vaz21_09 directory. Before coming to the rest part of this tutorial please check it. If there is no such a model there, you can download the model from the Internet using the following link: www.universalmechanism.com/download/90/vaz21_09.zip.

We will not consider in details how to create the model and come to nothing more than simulation its dynamics. It will give us a possibility not to introduce too many new terms and lead the reader into vehicle dynamics with Universal Mechanism slowly.

Acknowledgements

The model is used by the courtesy of Prof. Alexander Gorobtsov and was originally created in his FRUND software.

1.1. Loading the model

Now we will run **UM Simulation** program, load the VAZ 2109 model and perform several dynamical tests.

1. Run **UM Simulation** program (**Start | Programs | Universal Mechanism 9.0 | UM Simulation**).
2. Load the model from the {UM Data}\ SAMPLES\automotive\vaz21_09 directory, menu command **File | Open object**…

Now the model is loaded, see Figure 1.1.

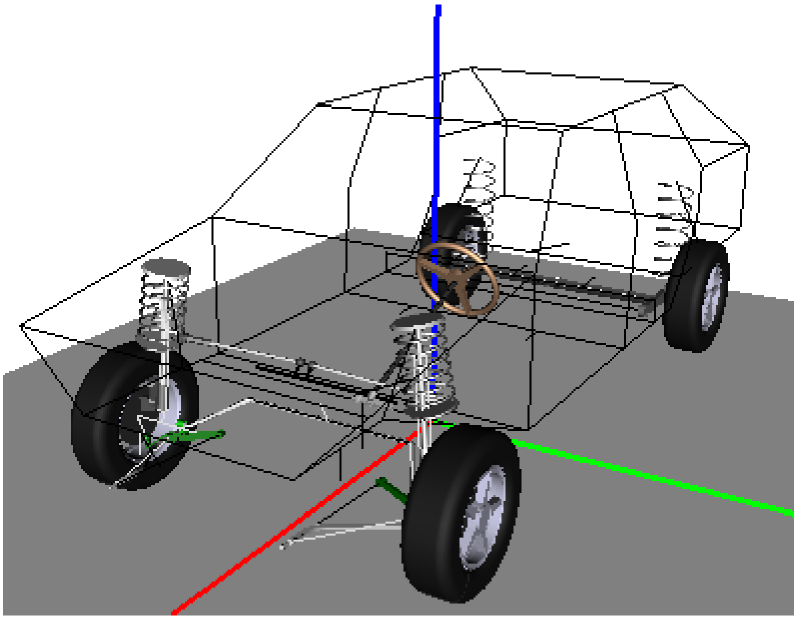


Figure 1.1. UM model of VAZ 2109

1.2. Equilibrium position

Each research of car dynamics should start with determining the equilibrium position. As a rule the position of the model at zero coordinates is quite far from its equilibrium position. To avoid a transient process in the beginning of each numerical experiment we need to find the equilibrium position of the car and always start numerical simulation from the equilibrium position.

Before going to a new test we will load beforehand prepared configuration, which includes animation and graphical windows, values of parameters of the model, parameters of a numerical methods as well as car specific parameters (road irregularities, tyre models etc).

1. From the menu **File** select **Load configuration** and then select the **Equilibrium Test**.

Note. **Load configuration** command loads the following files of the same name:

- *EquilibriumTest.icf* – animation and graphical windows;
- *EquilibriumTest.xv* – initial conditions;
- *EquilibriumTest.par* – values of parameters of the model;
- *EquilibriumTest.car* – car specific parameters.

One animation and one graphical window appear. There are four variables in the graphical window – vertical tyre forces for each wheel vs. time.

2. Select the **Analysis | Simulation**… or simply press **F9** key. **Object simulation inspector** appears.
3. In the **Object simulation inspector** select the **Initial conditions** tab. Here you can see that all coordinates and velocities are actually now equal to zero by default.
4. Select the **Road vehicle | Tests** tab. Make sure that **Equilibrium test** is selected as the current dynamical test.

Note. Simulation of road vehicle dynamics in Universal Mechanism software is based on ideas of dynamical tests. There are several tests: *equilibrium test, steering wheel rotation, open loop steering, closed loop steering* and others. See Chapter 12 *"Simulation of road vehicle dynamics"* of UM User's Manual.

5. In the **Object simulation inspector** click the **Integration** button. Numerical integration of equations of motion starts. It might take several minutes to finish these calculations.

Now we can see the motion of the model in the animation window and oscillations of vertical tyre forces in the graphical windows. We can see that 3 seconds is quite enough to bright the model to the equilibrium position.

Now we will save the final coordinates to a file of initial conditions, then set velocities to zero and thus obtain equilibrium position.

6. When the simulation process ends the **Pause** inspector appears. Let us save current (final) coordinates and velocities to a file of initial velocities. Click the **Save** button and save new file as **Equilibrium.xv**.
7. Close the **Pause** inspector by clicking the **Interrupt** button. **Object simulation inspector** appears.
8. Select the **Initial conditions** tab.

9. Click the button and load the **Equilibrium.xv** file.

10. Set velocities to zero by clicking button, see Figure 1.2.

11. Click the button and save the current set of coordinates and velocities in the **Equilibrium.xv** file once again. Now the **Equilibrium.xv** file corresponds to equilibrium position of the model.

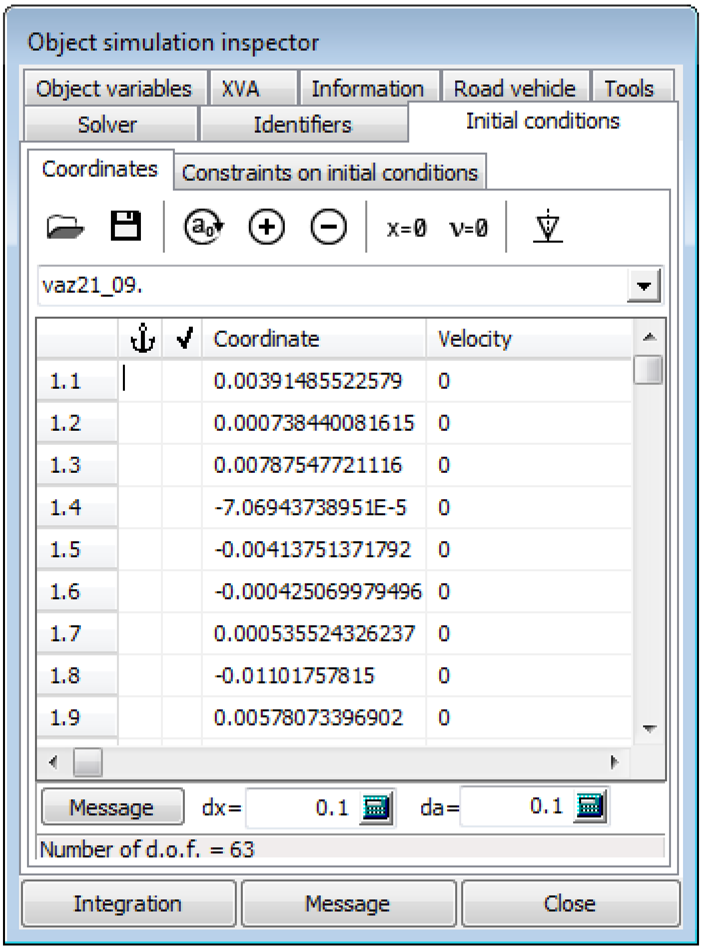


Figure 1.2. Initial conditions for the model

12. To load these initial conditions every time when the model is loaded the following settings should be done. From the **Tools** menu select **Options**. Then select the **Autosave** tab and turn on all the flags. Click **OK** and close the window.

Note. Only the **Initial conditions** flag in the **Autosave** tab concerns to initial conditions. However, it is recommended that you to turn on all flags. Such settings will lead to automatic loading last configuration of any model and correspondently loading all changes you have made in the model and its parameters.

Now when we turned on autosave options our model of VAZ 2109 will always load last initial conditions that correspond to equilibrium position of the car.

1.3. Steering wheel rotation test

Let us fulfill the “steering wheel rotation” test.

1. Load the **SteeringWheelRotation** configuration, menu command **File | Load configuration**.

This configuration includes two graphical windows. The first window shows steer angles vs. steering wheel angle. The second one – steer ratio vs. steering wheel angle.

2. Run numerical integration process (**Analysis | Simulation…, Integration**).

1.4. Open loop steering

Let us consider an example of simulation of VAZ 2109 dynamics with open loop steering. As an example let us set the steering wheel angle as time function as it shown in Figure 1.3. With steering wheel angle function our model should enter into turn fluently and then move in a circle.

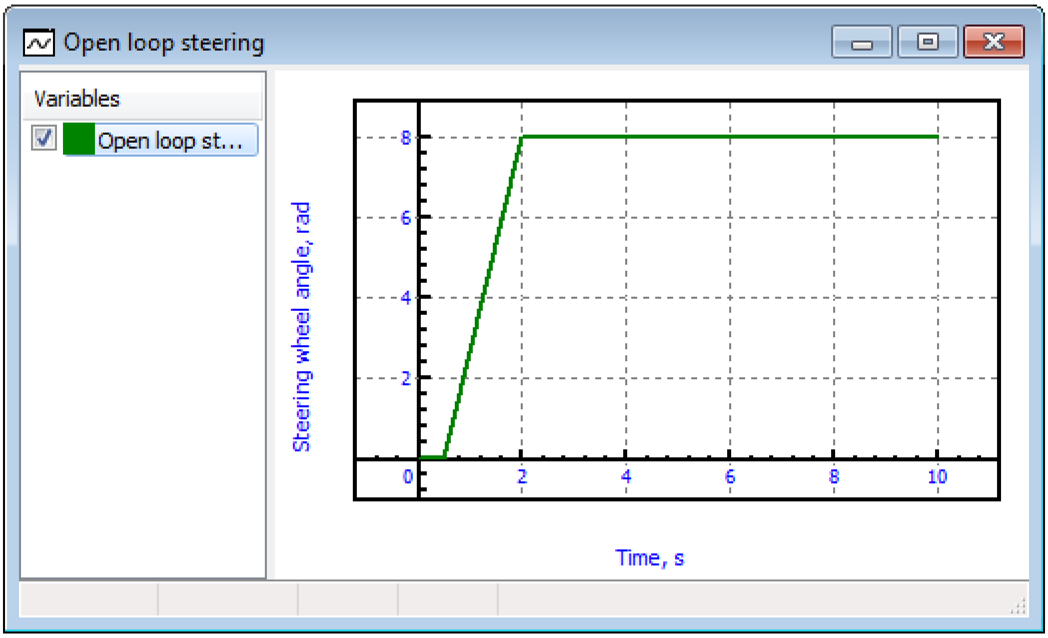


Figure 1.3. Steering wheel angle as a time function

1. Load the **OpenLoopCircle** configuration, menu command **File | Load configuration**.
2. Run numerical integration process (**Analysis | Simulation…, Integration**).

You can see the trajectory of the car in the graphical window, see Figure 1.4.

Note	It is more suitable to observe the trajectories with equal scale along axes of graphical window. To turn on equal scales option, please, do the following steps. Click right mouse button in the graphical window and in the context menu select **Options**. In the new window select the **Axes | Style** tab and turn on the **Equal scales** flag, see Figure 1.5.

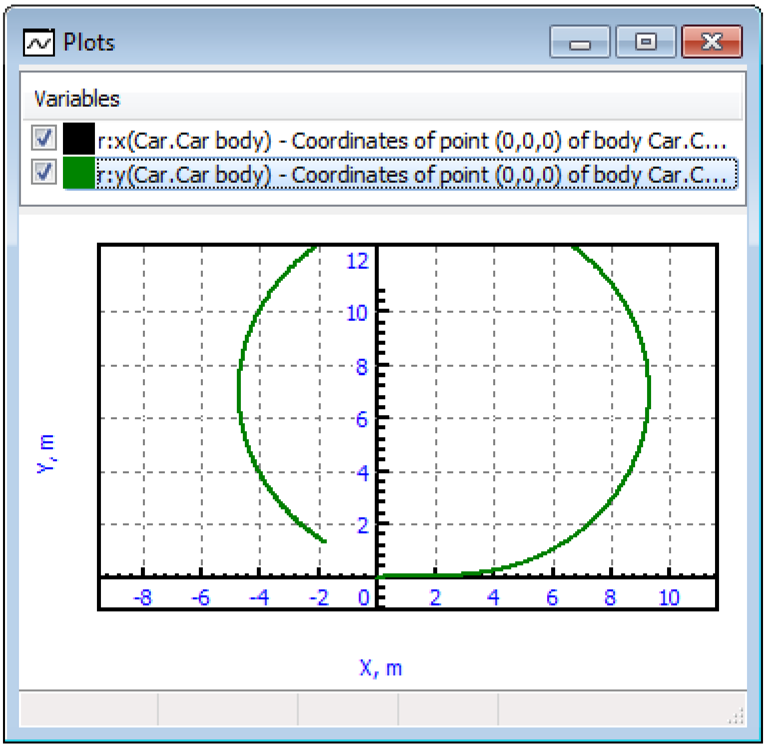


Figure 1.4. Trajectory of the center mass of the vehicle

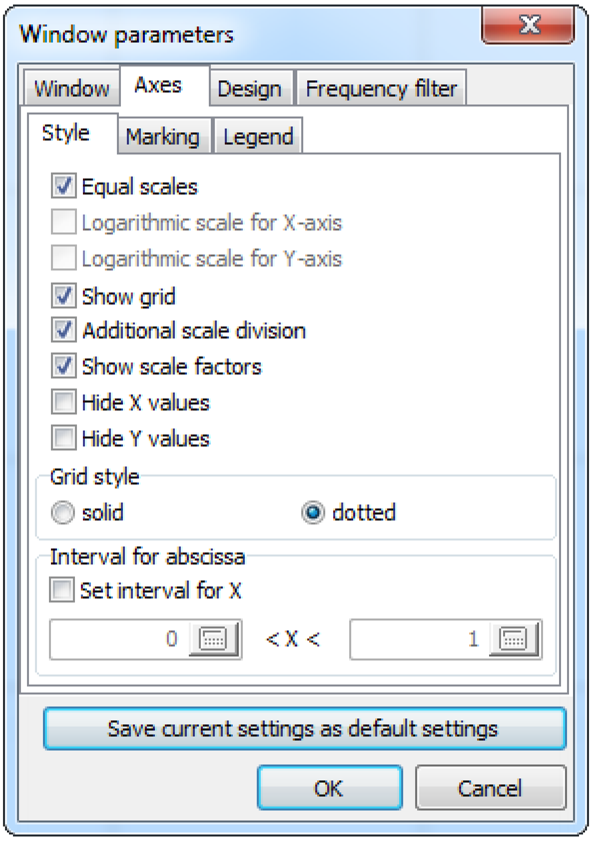


Figure 1.5. Parameters of graphical window

1.5. Taking off steering wheel

Now we will consider an example of the **«Open loop steering»** test. During this test steering wheel will rotate according the Figure 1.6, and then the steering wheel is taken off at the end point of the function in Figure 1.6.

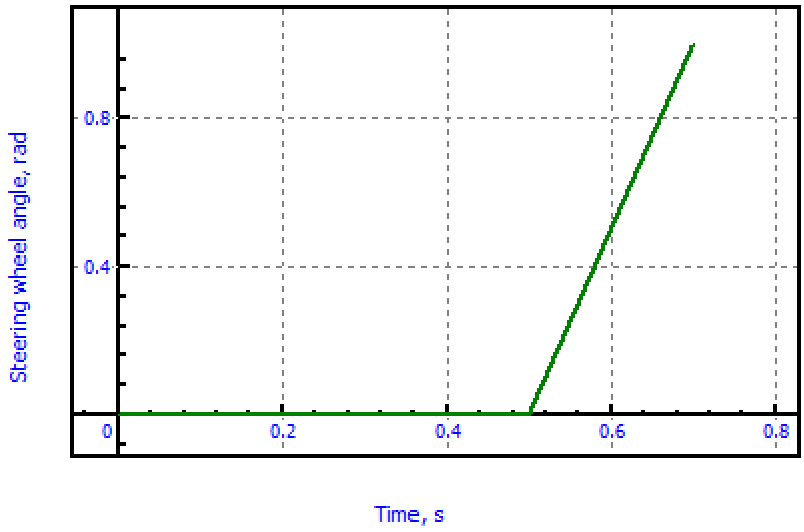


Figure 1.6. Steering wheel angle

1. Load the **WheelTakeOff** configuration, **File | Load configuration**.
2. Select the **Analysis | Simulation**… menu command. **Object simulation inspector** appears.
3. In the **Object simulation inspector** select the **Road vehicle | Tests** tab.

Please, note that the **"Open loop steering"** test is chosen (Figure 1.7) and **Terminal control** is **ON**.

<Terminal control = ON> means that the steering wheel is taken off at the end point of the function in Figure 1.6.

4. Click the button in the **Steering angle plot**. A new graphical window appears and shows the plot of the steering wheel angle.
5. Run the simulation process **(Analysis | Simulation…, Integration)**.

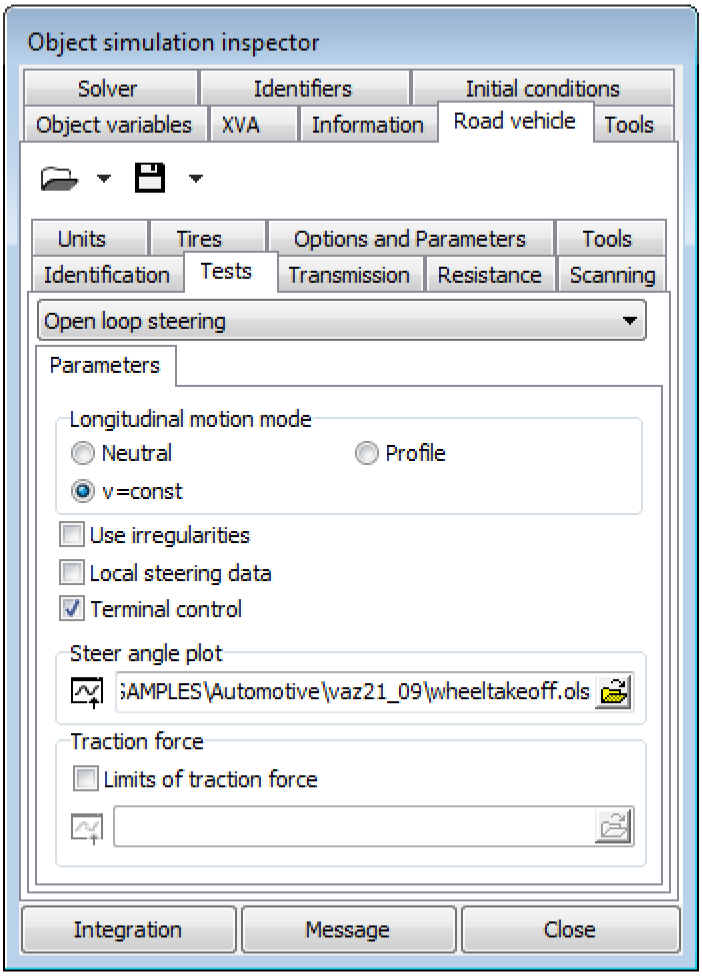


Figure 1.7. Open loop steering

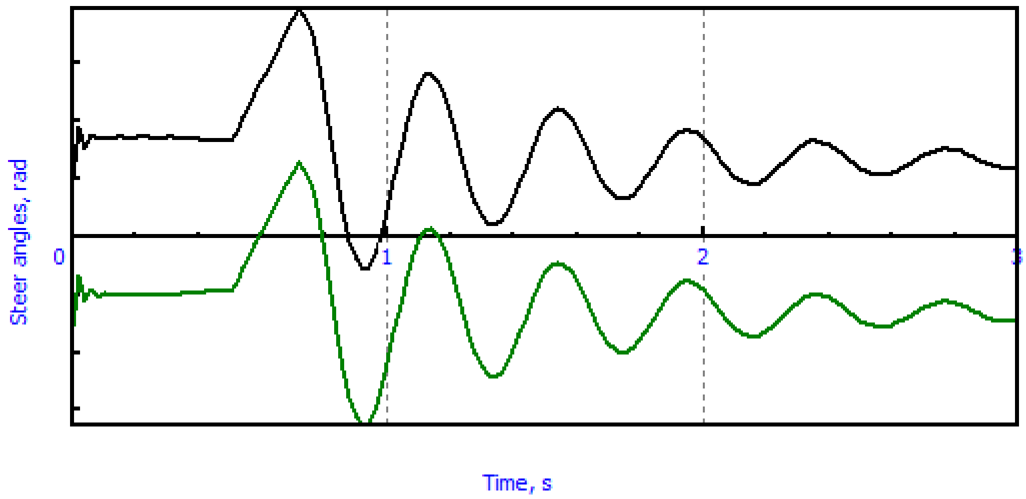


Figure 1.8. Steer angles

1.6. Double lane change maneuver

Let us consider a double lane change maneuver with closed loop control.

1. Load the **2sManoeuvre** configuration, **File | Load configuration**.
2. Select the **Analysis | Simulation** menu command. **Object simulation inspector** appears.
3. Select the **Road vehicle | Tests**, see Figure 1.9.
4. Desired path is described in the **2s.mgf** file, see Figure 1.9. To visualize the path click the  button. New graphical window with plot of desired path appears.

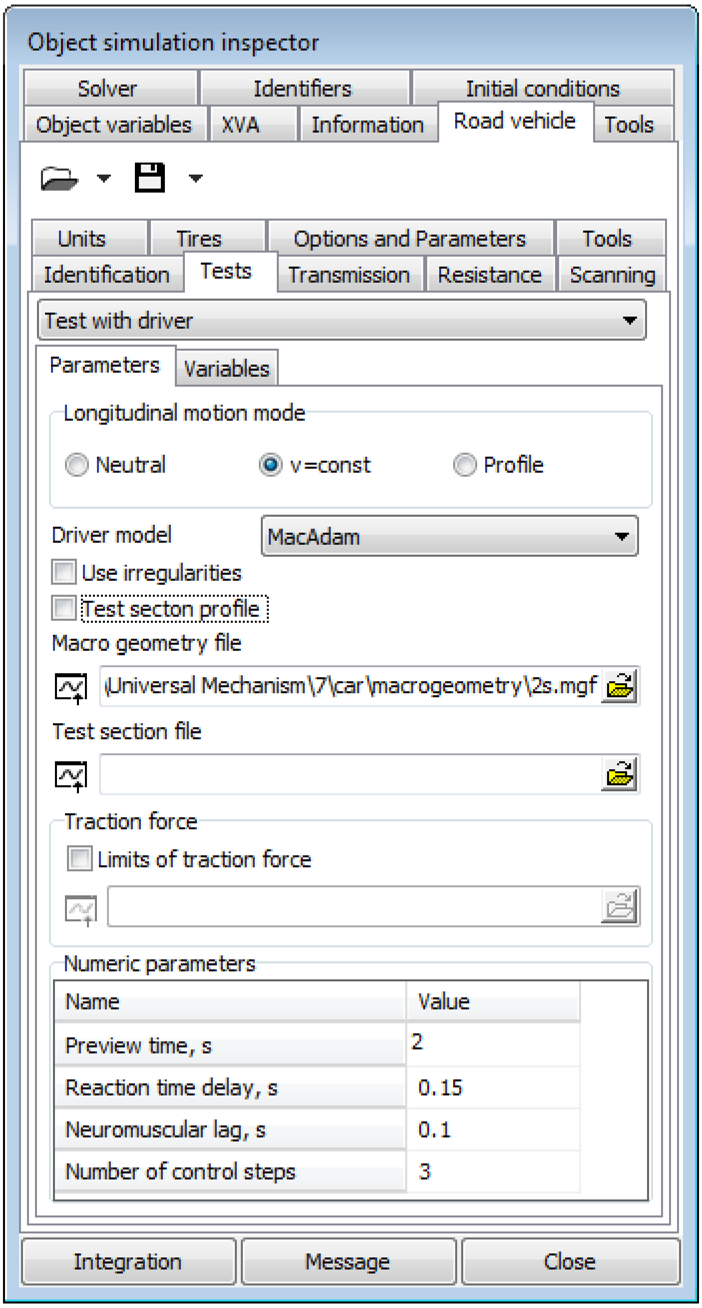


Figure 1.9. Double lane change

Note. **Marco geometry file** defines the *desired* path of the vehicle. To hold the vehicle on the desired path the one of the supported driver models is used. Driver controls the steering wheel and drives the vehicle close to the desired path. However the *real* path, which is obtained as a simulation result, is usually differ from the *desired* path. According to Society of Automotive Engineers (SAE) lane change the path of the vehicle, measured at the center of the steer axle, is required to not deviate by more than ±150 mm from a precisely prescribed path. There are more severe recommendations that require the path not to deviate by more than ±30 mm.

5. Run the simulation process (**Analysis | Simulation…, Integration**).

1.7. Linear analysis

1. Load the **Linear Analysis**, menu command **File | Load configuration**.

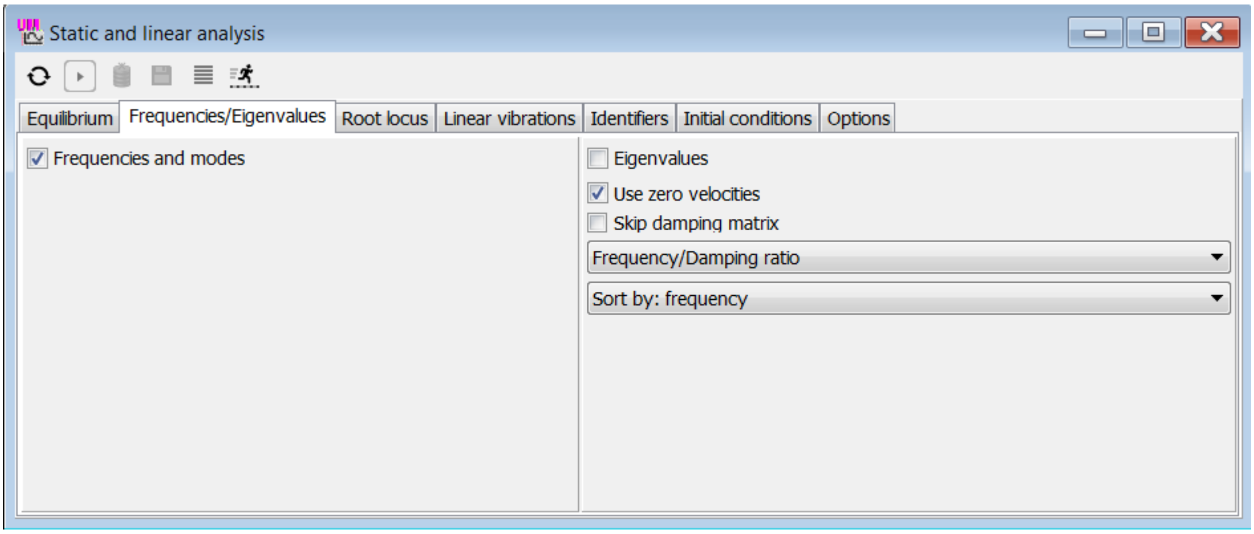
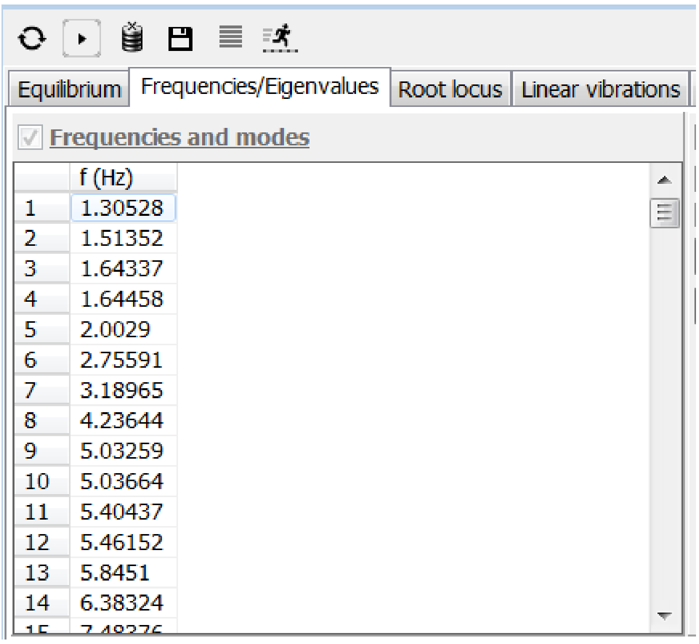


Figure 1.10. Window of static and linear analysis

2. From the menu **Analysis** select the **Static and linear analysis…** command. Window of analysis appears, Figure 1.10.



3. Figure 1.11. Table with natural frequencies

3. Click on the button to compute natural frequencies of the model, see Figure 1.11.

4. Click the button or double click on a frequency in the table to animate the corresponding natural mode in the animation window.

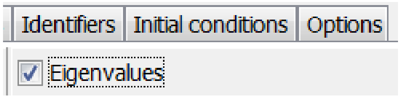


Figure 1.12. Key for eigenvalues

5. Check the key for computation the model eigenvalues (roots), Figure 1.12, and click on the  button. The eigenvalues are located in the right part of the window, see Figure 1.13.

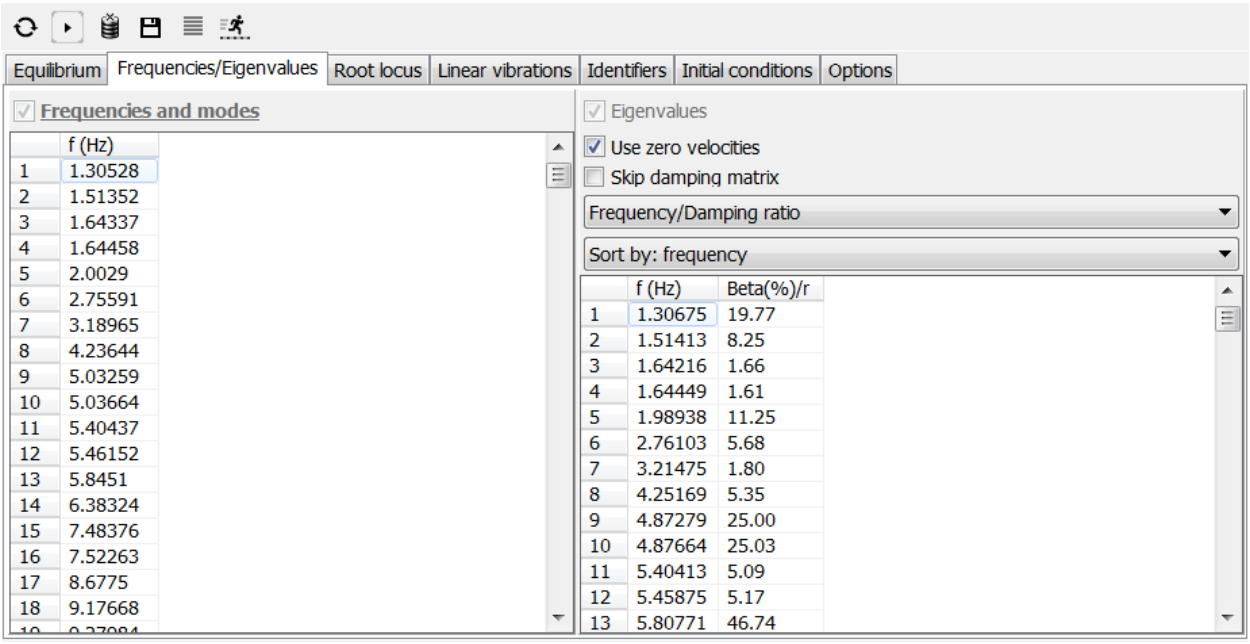


Figure 1.13. Natural frequencies (left) and eigenvalues (right)

By default, the eigenvalues are written in the **Frequency/Damping ratio** mode, which allows the user to evaluate the damping rate for each of the modes.