Team-Exercises for DGC 100 Modelica Course

Hubertus Tummescheit
United Technologies Research Center, East Hartford, CT 06108.

November 4, 2003

Abstract

This document is a preliminary version and is going to be upgraded weekly.

1 Model Structure

A variety of different models is needed for the development of the controls and the performance assessment of the Chevy Tahoe. The goal of this DGC 100 course project is to provide these models for the controls development and the insight gained by exercising these models.

2 Models

For this week the exercise consists of three parts:

1. Develop astructure of the model library that allows to reuse as many model components as possible for the different tasks. It is for example possible to share simple models for the powertrain for all the models mnetioned below.

2. A one-dimensional inertial model for the development of a simple cruise control and braking.

3. A simple, equation-based 2-dimensional model for steering and path-planning

For the structuring, take hints from the VehicleDynamics libary and the SimpleCar library. The team should present the structure at the beginning of the next lecture. Explain the reasons for your decisions.

The equations of motions for the first two models are given in the next subsections. The structuring of the models is at the discretion of the team.

Coordination of the data and parameters needed for all the models is done by Dave van Gogh. I suggest to have a master-document with all parameter data at a central location, e.g. the CVS repository.

2.1 Inertial model

The inertial model captures the longitudinal (backwards and forward) motion of the vehicle. The equations of motion are:

$$
\begin{aligned}
\dot{x} = v & & \\
m\dot{v} &= -b * v + F_{wheels} + F_g \\
\dot{\tau} &= -a * \tau_{axle} + c * u_t \\
\tau_{axle} &= \begin{cases} K_{pt} * \tau_i & \text{if accelerating} \\ K_{brake} * \tau_{brake} & \text{if braking} \end{cases} \\
F_{wheels} &= R_{wheel} * \tau_{axle} = R_{wheel} * K * \tau
\end{aligned}
$$

where we have:

$$
\begin{aligned}
m &= \text{mass of vehicle} \\
b &= \text{effective damping coeffient} \\
a &= \text{first order lag coefficient} \\
c &= \text{conversion between throttle position and engine torque} \\
\tau_i &= \text{engine torque for gear i} \\
\tau_{brake} &= \text{brake torque} \\
\tau_{axle} &= \text{axle torque} \\
v &= \text{speed of vehicle} \\
F_{wheels} &= \text{force from ground to wheels} \\
F_g &= \text{gracity force for uphill or downhill driving} \\
u_t &= \text{throttle input} \\
K_{pt} &= \text{torque conversion from engine through transmission through differential} \\
K_{brake} &= \text{torque conversion from brake actuator to brake}
\end{aligned}
$$

Inputs, parameters and outputs for the model:

1. Inputs
   - u_t, the throttle position
   - Braking position (needs to be included in model - is not now)
   - Loads (wind, rolling resistance, grade, etc.)
2. Parameters
   - Mass
   - gear switch stratgy (implicit in τ_i)
   - Braking signal vs. braking force
   - Torque curves from engine τ_i (for each gear).

3. Outputs

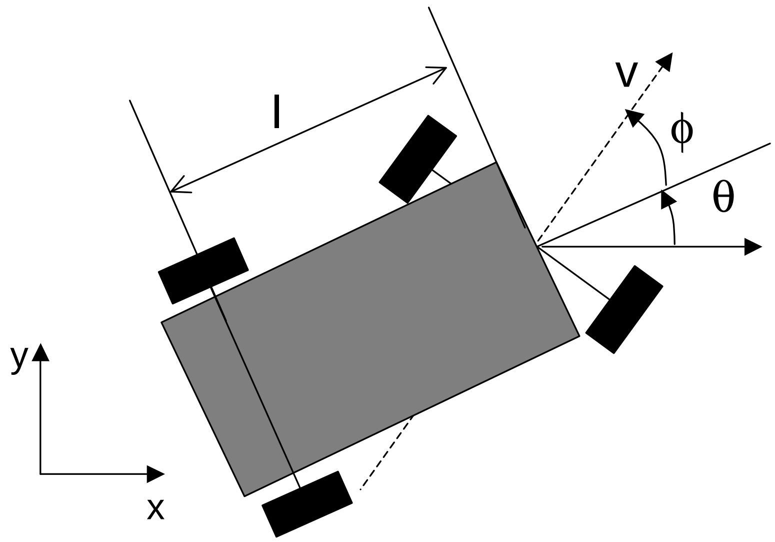

Figure 1: Schematic of a simple planar car model.

- x and y are cartesian coordinates of the fixed world coordinate system.
- ϕ = front wheel angle (+ is turning left)
- x = forward direction
- y = vehicle position along the y-axis
- ω = angular velocity of vehicle

- v = speed of vehicle in direction of front wheels

The equations of motion are:

$$\begin{aligned}
\dot{x} &= v * \cos(\phi + \theta) \\
\dot{y} &= v * \sin(\phi + \theta) \\
\dot{\theta} &= \frac{v}{l} \sin \phi \\
\dot{\phi} &= u
\end{aligned}$$

The velocity can either be constant or another input.

1. Inputs
   - $u = \dot{\phi}$ = steering angle rate
   - v = forward speed of rear axle
2. Parameters
   - l = wheelbase (axle-to-axle distance)
   - Limits on steering angle ϕ_{min}, ϕ_{max}
   - Limit on steering rate ω_{max}.
3. Outputs
   - x-coordinate
   - y-coordinate
   - angle θ

Questions about this model can also be directed to Lars Cremean whos is going to use them for controls development.

2.3 Planar model for inertia and kinematics using the planar Multibody-Systems library

The planar model should share as many components as possible with the previous model and even with the 3-D model. In particular, the following components can be shared:

- 3-D wheels. This may be surprising, but the 3Dto2D-connector of the PlanarMultiBody library has been designed for exactly this purpose. This does of course not reproduce the same behavior as a full 3-D model, but lateral forces can be evaluated under the assumption that the tire normal force is constant (this follows from the 2-D assumption).
- The powertrain up to the exit of the gear box is shared with the 1-D model, the final power train can be the same as in the 3-D model.
- The brake torque curve is the same for models.
- A simple “driver” model is useful for manouever-testing.

2.4 3-Dimensional vehicle dynamics model

Will be defined later. This model should use the components from the VehicleDynamics library. The collection of measurements and data should begin as soon as possible.

2.5 Loads and Environment

Loads and environment have to be different for the models, becasue the interaction with the model is different. Possible “loads” are:

- Wind resistance for the 2-D and 3-D models (attention: wind resistance is included in the 1-D dynamics!),
- driving through shallow water,
- extra weight on the truck and
- Gravity load from uphill-downhill driving for all models except the 3-D model, where this comes automatically from the road model.

The only environment model that is needed is the road for the 3-D vehicle. Road modeling could be a small sub-project for anybody who is interested.

3 References

Many of the references can be downloaded in full-text format from the Modelica Website, `http://www.modelica.org`, therefore the links are given as urls. (To be completed)