Laboratory Assignments for the course
Multibody Dynamics A, wb1310,
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Alternative Assignment 5

In order to examine the lateral stability of a bicycle we make a model in ADAMS. The bicycle is modelled by four rigid bodies connected by hinges: the rear wheel, the frame with a rigid rider attached, the fork and the handlebar assembly being the front frame, and the front wheel. For the geometry and parameter values we follow the bicycle benchmark paper from Meijaard *et al.* [1]. This also give us room to compare results. However, in this paper the contact of the wheels with the level ground is modelled by idealized pure-rolling constraints (nonholonomic constraints). Unfortunately, these type of constraints are not present in the ADAMS software and therefore we will model the wheel contact by compliant tires. For the tires, we will make use of the **Delft-Tyre** Model. The Tyre Property Files for front and rear tires are `bicycle700c.tir` and `bicycle600c.tir` and the Road Data File `FlatRoad.rdf` describes a flat level road. These files can be found on the course website.

1. Make a model of the bicycle in ADAMS. Let this model drive straight ahead at a low initial speed (≈ 1 m/s) in order to prove that your model is working.
2. Simulate the motion of the bicycle for 5 seconds. The initial conditions are an upright position with the steering straight ahead, an initial forward speed of 4.6 m/s, an initial lean angular velocity, for the whole assembly, of 0.5 rad/s, and zero steering rate. Give a clear representation of the motion in a number of graphs of your own choose. Compare your results with those from Figure 4 of the benchmark paper [1].
3. Use your simulation to address one or more of the following questions (or some of your own):
   (1) Below 4.3 m/s and above 6.0 m/s the bicycle is unstable. However, these instabilities have different characteristic motions. Demonstrate these instabilities by transient analyses on the ADAMS model and characterize the different motions.
   (2) A folklore in bicycle science is that he wheel reaction forces in the contact point are in the plane of the wheel. True or not?
   (3) Does the bicycle have any stable motions besides upright straight ahead?
   (4) By changing mass and geometry parameters, what's the slowest speed for which you can find a stable bicycle?

References

[1] J. P. Meijaard, Jim M. Papadopoulos, Andy Ruina, and A. L. Schwab. Linearized dynamics equations for the balance and steer of a bicycle: a benchmark and review. *Proceedings of the Royal Society A*, 463:1955–1982, 2007.