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Simulation and Control of the *Anaconda*

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Abstract

The *Anaconda* project consists in designing an articulated in-line polycycle propelled by man power and able to follow any winding road.

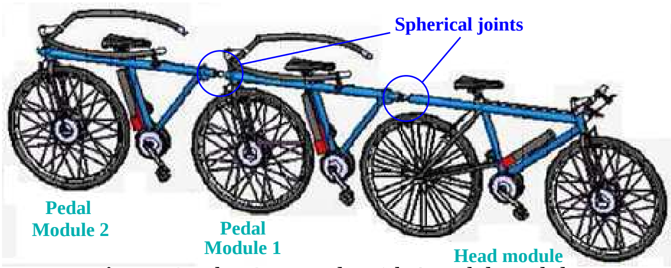

Figure 1. The *Anaconda* with 2 pedal modules

The Anaconda (Figure 1) consists of a Head Module (HM), which resembles the traditional bicycle, followed by several Pedal Modules (PM) connected to each other by spherical joints. As the purpose is to allow a maximum number of modules, it appears that each module must be fitted with a handlebar in order to control itself its equilibrium. On the contrary, the motricity and the brake system should be centralized. This aspect will not be considered in this paper which will focus on the stability of the Anaconda and try to demonstrate that its handling is possible.

The dynamics of the Anaconda has been modeled according to the multibody theory, with the help of the EasyDyn framework [1], based on the minimal coordinates approach. Three models have been developed: the HM alone (5 bodies and 10 dof), the PM alone (4 bodies and 6 dof) with the attachment point constrained to follow a straight line, and finally an Anaconda with a HM and 2 PM (13 bodies and 22 dof). In all models, the rider body lean is frozen and tires are considered through contact forces calculated according to the model of the University of Arizona [2].

To stabilize the first two systems, the effect of the biker is introduced through a controller whose output is a torque applied on the handlebar as usually considered in bicycle models [3]. To design the controllers, systems are linearized about a stationary state where the module is ridden in straight line, at the velocity of 20 km/h on a flat level surface. Only the out-of-plane behavior is retained, the number of concerned dof coming down to 4 for the HM and 3 for the PM respectively: the lateral displacement (for HM), the yaw and the roll angles of the module's frame and the steering angle. Optimal state feedback controllers have been designed according to a LQG approach. So far, no observer has been included in the model and all state variables are assumed to be available.

The optimal controllers have then been successively tested on the complete nonlinear models of the HM and PM alone. It is observed that the torques necessary to control the vehicle fit to the human possibilities. Moreover, in order to demonstrate the manoeuvrability of the complete polycycle, the controllers established on the independent modules have been put on the complete model and lead to a stable behaviour. For the purpose of illustration, Figure 2 shows the results obtained during a lane-change. This result is encouraging as it shows that the equilibrium skills acquired during the learning process on a single module contribute to the global equilibrium. On another side, the rideability index describes by Seffen et al in [4] was evaluated for some Anaconda models with the amount of the PM up to 9 ; and as we can except this index increases with the PM amount.

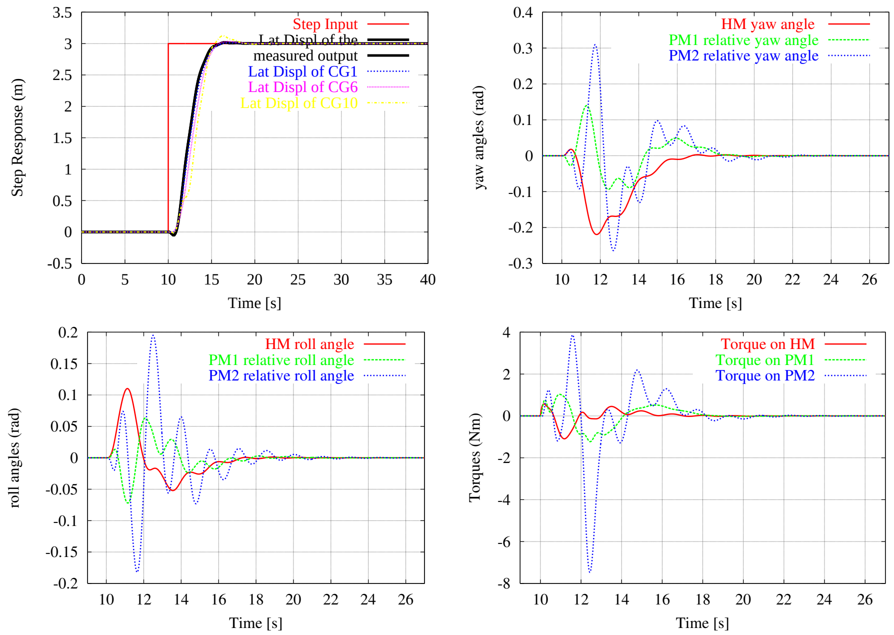

Figure 2. Time histories of modules motion (lateral displacement, yaw and roll angles) and steering torques

In parallel, a prototype with a HM and 2 PM has been built (Figure 3) and it appears that after some training, the bikers are able to follow usual trajectories.

Figure 3. An *Anaconda* prototype

In this work, a multibody model of the Anaconda has been established, from which its manoeuvrability can be hopefully considered as realizable by standard human people. First tests on a prototype with 2 PM modules have confirmed this statement. The future prospectives are to validate the obtained controllers with respect to the human behaviour, so as to use the model to optimize the mechanical design of the polycycle in terms of stability and manoeuvrability.

References

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