Dynamics and Control of a Gyroscopically Stabilized Cart

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Abstract: Vehicle rollovers are a priority of the US Department of Transportation - NHTSA (National Highway Traffic Safety Administration). Rollover crashes represent about 1/5th of all fatal crashes. Large truck rollovers cost 608 lives in 2003 in the US. One source of rollover accidents is the use by large trucks of roads that have dangerous geometry (particularly curves). In this paper, we develop dynamic equations and propose a controller design for a gyroscopically stabilized cart. This scaled model is developed to study rollover conditions for vehicles and to prototype possible anti-rollover systems.

We model the nonlinear dynamics of the cart and gyroscope using Lagrange's method. We then develop a linearized model, and a linear controller. We compare this to a nonlinear controller designed for the nonlinear model. In the cart design, destabilizing forces are resisted by a gyroscope, which is driven by a (DC) motor. The gyroscope here is used as an actuator, not a sensor, by using precession forces generated by the gyroscope. When torque is applied to an axis normal to the spin axis, a gyroscope reacts by turning on a third axis, orthogonal to both the torque and spin axes. We consider a scaled system, good for proof of concept, formed of a cart, a gyroscope, and a DC motor. Dynamic modeling, controller design, and simulation results are presented.

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