Real-time simulation for a multi-wheeled ground vehicle

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Abstract

A military unmanned ground vehicle (MUGV) is a vehicle which is operated without human onboard for short-range surveillance and reconnaissance. This MUGV has to control driving velocity and direction by estimating road roughness. To predict the limit stable velocity profile of the vehicle driving off-road, driving speed estimation concept using a dynamic analysis is proposed [1]. A single prediction process needs a single full driving simulation along a given path as shown in Figure 2, so highly efficient dynamic model and simulation technique are required for real-time analysis. For accurate analysis, vehicle is modeled with multi-body model which has simplified translational spring damper actuator model (TSDA) and Fiala tire model.

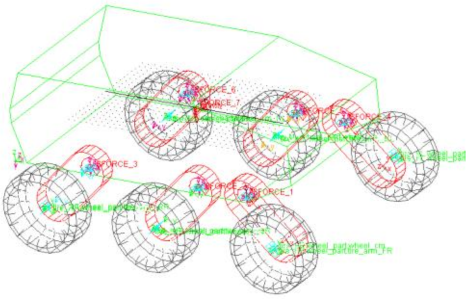

Figure 1: Multi-body modeling of MUGV

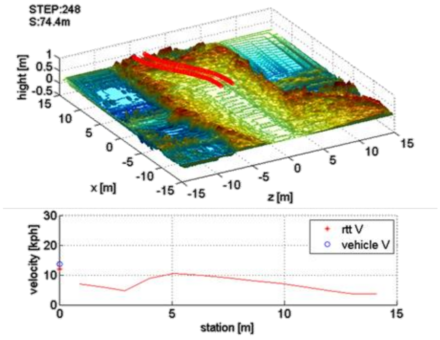

Figure 2: Locally estimated velocity profile

As shown in Figure 1, the MUGV consists of chassis, six rotating suspensions and wheels with in-wheel motors. The vehicle's equation of motion model is formulated with velocity transformation technique using joint coordinates [2]. And MUGV does not have cut-joint, so equation of motion is expressed with equation (1, 2, 3).

$$\bar{\mathbf{M}}(\mathbf{q})\ddot{\mathbf{q}} = \bar{\mathbf{g}}(t,\mathbf{q},\dot{\mathbf{q}}) \tag{1}$$

$$\bar{\mathbf{M}} = \mathbf{B}^T\mathbf{M}\mathbf{B}, \quad \bar{\mathbf{g}} = \mathbf{B}^T\left(\mathbf{f} - \mathbf{M}\dot{\mathbf{B}}\dot{\mathbf{q}} - \mathbf{h}\right) \tag{2}$$

$$\dot{\mathbf{y}} = \mathbf{B}\dot{\mathbf{q}}, \quad \ddot{\mathbf{y}} = \mathbf{B}\ddot{\mathbf{q}} + \dot{\mathbf{B}}\dot{\mathbf{q}} \tag{3}$$

To consider transient tire behaviors, relaxation length concept is applied to calculate slip ratio and slip angle as shown in Figure 3 [3, 4]. In case of low speed driving or stand still simulation, ODE of relaxation length, which is expressed with equation (4, 5), is stiffer than multi-body dynamic model [5]. To improve robustness of integration, time delay of tire force is forced to be limited.

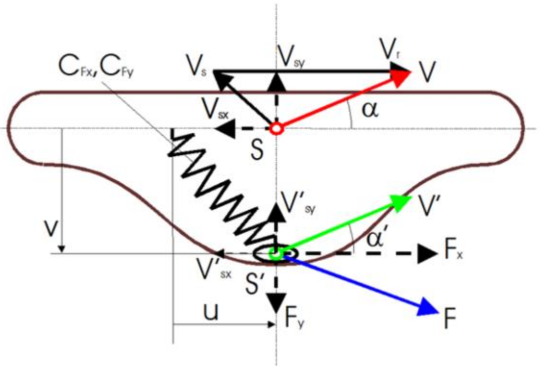

Figure 3: Mechanical model of transient tire behavior. [3]

$$\sigma_\alpha \frac{d\alpha'}{dt} + |V_x|\,\alpha' = -V_{sy} \tag{4}$$

$$\sigma_\kappa \frac{d\kappa'}{dt} + |V_x|\,\kappa' = -V_{sx} \tag{5}$$

Simulation cost is limited and prediction time rate is fixed, so predictor-corrector explicit form of generalized-α method is applied to time integration for robust and efficient simulation [6]. And quasi-static equilibrium analysis is performed by using finite displacement technique like integration without updating the velocities. From these methods, this paper shows that a fixed large step size for simulation of the MUGV is possible on the explicit integrator.

Acknowledgement

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