Reduced-order compliant wheel–obstacle Contact interaction for rover mobility with experimental validation

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Compliant wheels are preferred over rigid wheels in situations that require improved ground contact, such as off-road vehicles on rugged terrain. Simulating compliant wheel interactions is generally computationally expensive, often requiring the use of finite-element modeling to capture large deformations. This motivates the development of new methods to reduce the computational workload required to accurately model compliant wheels.

In this work, we present an efficient way of capturing the effect of deformation within a rigid wheel modelling framework by adjusting the contact parameters of a rigid wheel model. Instead of explicitly modelling for any structural deformation, the approach uses the constrained kinetic energy at the moment of contact to represent the effect of deformation in a simple and computationally efficient manner.

The method is based on projecting the motion of the rigid wheel into the space of constrained motion, following the formulation introduced in Ref. [1, 2]. With this projection, we can calculate the portion of kinetic energy aligned with the active constraint direction. The constrained kinetic energy is then used to calculate an equivalent radial deformation that happens during the contact with the obstacle using an effective stiffness. This deformation is used to update the contact point and the normal direction within the rigid wheel contact model, as illustrated in Fig. 1, allowing the rigid model to reflect the behaviour of a compliant wheel without modelling the tire structure.

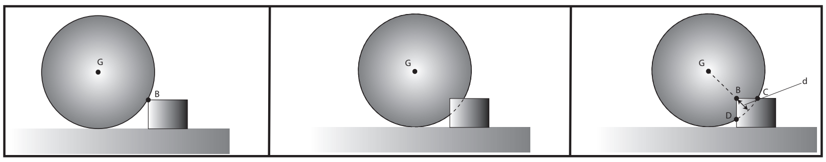

Figure 1: Schematic of deformation-based contact adjustment. The constrained kinetic energy provides deformation d, which is used to update the effective contact point from the obstacle edge to point C.

Building on the single-wheel formulation, we implement the reduced model in a complete rover multibody dynamics simulation. Each wheel of the rover uses the deformation-based update of the contact parameters, allowing the vehicle to reproduce compliant-wheel obstacle negotiation behaviour while retaining real-time performance. The model will be used to run obstacle traversal simulations across various obstacle heights, velocities, and stiffness values. In parallel, an instrumented rover platform is being used for experiments in which identical obstacle configurations are used to validate the simulation results by comparing wheel loads, motion, and climb outcomes.

References

[1] J. Kövecses, Dynamics of mechanical systems with motion constraints, *Journal of Applied Mechanics*, 75, 2008.

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