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A NONLINEAR A-PRIORI HYPER-REDUCTION METHOD FOR THE DYNAMIC SIMULATION OF A CAR TIRE ROLLING OVER A ROUGH ROAD SURFACE

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During the design process of a tire, many different performance areas need to be balanced. Due to high computational loads, the use of numerical tire models remains limited for many of these performance areas. The numerical tire models are typically nonlinear structural finite element (FE) models with a very large amount of degrees of freedom (DOFs), described by a system of nonlinear dynamic equations of the following form:

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{f}\left(\mathbf{u}, \dot{\mathbf{u}}\right) = \mathbf{f_e}\left(\mathbf{u}\right). \tag{1}$$

In this equation $\mathbf{M} \in \mathbb{R}^{n\times n}$ is the mass matrix, $\mathbf{f} \in \mathbb{R}^n$ the nonlinear internal and gyroscopic force vector and $\mathbf{f_e} \in \mathbb{R}^n$ the nonlinear external forces acting on the tire (i.e. air pressure and tire/road contact forces). Due to the large amount of degrees of freedom and computational costs related to the evaluation of the nonlinear force terms and tangent stiffness matrices, model order reduction applied to the set of equations (1) is necessary to allow for sufficiently low computational times to exploit these models during the design process.

However, most model order reduction approaches for nonlinear FE reduction, like Energy Conserving Sampling and Weighting (ECSW) [1], rely on dynamic training simulations to set up the reduced order model. In practice this training is often infeasible, and therefore in this work an a-priori model order hyper-reduction scheme [2] is proposed. This approach uses a constant nonlinear reduction basis and an L1 optimization for element sampling, both calculated/performed a-priori. The approach is validated on a nonlinear FE tire model rolling with a constant angular velocity over a rough road surface. Solving the hyper-reduced set of equations offers significant speed-ups, even when including the pre-processing costs, while still retaining a high accuracy.

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