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A sonification algorithm for developing the off-roads models for driving simulators

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ABSTRACT

In this paper, a sonification algorithm for developing the off-road models for driving simulators, is proposed. The aim of this algorithm is to overcome difficulties of heuristics identification which are best suited to a particular off-road profile built by measurements. The sonification algorithm is based on the stochastic polynomial chaos analysis suitable in solving equations with random input data. The fluctuations are generated by incomplete measurements leading to inhomogeneities of the cross-sectional curves of off-roads before and after deformation, the unstable contact between the tire and the road and the unreal distribution of contact and friction forces in the unknown contact domains. The approach is exercised on two particular problems and results compare favorably to existing analytical and numerical solutions. The sonification technique represents a useful multiscale analysis able to build a low-cost virtual reality environment with increased degrees of realism for driving simulators and higher user flexibility.

1. Introduction

Recently, substantial progress was made in solving nonlinear equations with random input data defined by its mean and correlation function [34,24]. The off-roads models for driving simulators can be viewed as constraint satisfaction problems in which the sonification algorithms may repeatedly assigns values to variables, terminating when all constraints are satisfied. In this paper we suggest a version of the sonification algorithm based to the stochastic polynomial chaos analysis for solving the 3D normal contact problem with friction for off-roads driving simulators [32,7,41]. The aim is to overcome the difficulties of identification of unsatisfied constraints for a particular off-road profile. The randomly character of the stiffness and damping in the contact interfaces, due to vibro-impacts and frictional slips hampers developing the off-road models for driving simulators [25,43,19,12,3]. It is known that, the friction model changes the characteristics of the vibro-impact phenomenon in terms of duration, dissipation of energy, accelerations and decelerations. In turn, the vibro-impact dynamics changes the friction pattern by the appearance of the micro-slips consisting of elastic and plastic deformation [15,22,31,23]. The sonification algorithm comes to solve these problems by treating the random fields as elements of Hilbert space [30,16,38]. The unknown coefficients in the polynomial chaos expansion are identified by using a genetic algorithm. The sonification algorithm uses the geometric properties of hardly detectable details of the real off-roads and random properties of different

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cross-sectional slices of images furnished by the transformation map [25,27,36]. For existing data for shape and curvature, it is important to discover of more or less hidden information in what concerns the contact tire/off-road, to help the performance of the developed algorithms [4,11,17,39].

The scheme of contact between the tire and the off-road is represented in Fig. 1, where F_c is the contact force, F_{tx} the longitudinal component of the friction force acting in the X direction, F_{ty} the lateral component of the friction force acting in the Y direction, and α the angle between the direction X and the direction of travel.

We will focus in this paper on the evaluation of the off-road models related to the sonification algorithms and polynomial chaos expansion technique, which were not done previously in the literature.

The paper is organized as follows: Section 2 is devoted to the formulation of 3D normal contact problem with random contact domains. In Section 3, the polynomial chaos expansion of the solutions is presented together to the probabilistic collocation method to find the unknown parameters. Results are reported in Section 4. Comparisons to existing analytical and numerical solutions are provided by Section 5, while some Conclusions are drawn in Section 6.

2. The 3D normal vibro-contact problem

This Section describes a virtual experiment concerning driving on off-roads designated to build an off-road simulator. The tire tread is modeled as an elastic half-space [32]. The model of the contact tire/road is displayed in Fig.2.

The random contact domain is denoted by D_c, and (ξ, η) coordinates describe points within D_c, P_0 is the total load applied to the tire, and $h_s(X, Y)$, $h_t(X, Y)$, $\Delta(X, Y)$ are the height of the road surface, the height of the tire and the total penetration between the elastic half-space and the road surface, respectively, linked to δ_z by

$$\delta_z = h_t - h_s - \Delta. \tag{2.1}$$

The normal contact pressure $p(\xi, \eta, t)$, the tangential loading in the positive X-direction $q_X(\xi, \eta, t)$, and the tangential loading in the positive Y-direction $q_Y(\xi, \eta, t)$ on the tire, are given by

$$p = p(\xi, \eta)\delta(\xi)\delta(\eta)\exp(i\omega t), \quad q_X = q_X(\xi, \eta)\delta(\xi)\delta(\eta)\exp(i\omega t), \quad q_Y = q_Y(\xi, \eta)\delta(\xi)\delta(\eta)\exp(i\omega t), \tag{2.2}$$

where $\delta(\cdot)$ is the Dirac delta function. The normal contact between the tire and the road is described by Boussinesq equations [8,10,26]

$$\delta_x(X, Y) == \iint_D \frac{p(\xi, \eta)(X - \xi)(1 - \nu^2)}{\pi E((x - \xi)^2 + (y - \eta)^2)} d\xi d\eta \text{ in } D, \tag{2.3}$$

$$\delta_y(X, Y) == \iint_D \frac{p(\xi, \eta)(Y - \eta)(1 - \nu^2)}{\pi E((x - \xi)^2 + (y - \eta)^2)} d\xi d\eta \text{ in } D, \tag{2.4}$$

$$\delta_z(X, Y) == \iint_D \frac{p(\xi, \eta)(1 - \nu^2)}{\pi E\sqrt{(x - \xi)^2 + (y - \eta)^2}} d\xi d\eta \text{ in } D, \tag{2.5}$$

The equilibrium condition is

$$-P_0 = \iint_D p(\xi, \eta) d\xi d\eta. \tag{2.6}$$

Let us introduce the notations: δ_x, δ_y, δ_z the tire-tread displacements due to the normal load only, D the surface of half-space, E the Young's modulus of the half-space and ν the Poisson's ration of the half-space, P is the total load applied to the tire, h_s the height of the road surface, h_t the height of the tire, Δ the total penetration between the elastic half-space and the

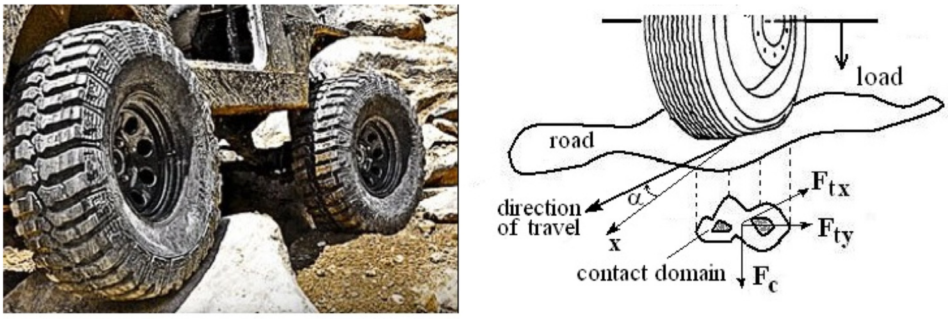

Fig. 1. Scheme of the contact tire/off-road.