Hamiltonian Monte Carlo with application to train-track-bridge coupled interactions subjected to seismic excitation with uncertainties

Wandji Zoumb Patrick Arnaud (moi_zoumb@yahoo.fr)
Southwest Jiaotong University https://orcid.org/0000-0002-1449-6604

Research Article

Keywords: Train-track-bridge interactions, Earthquake, Hamiltonian Monte Carlo, Naïve stochastic gradient.

Posted Date: April 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-427846/v1

Abstract

Numerical models of train running over the bridge are prone to errors and random excitation sources, which inevitably influence the capacity of such models to accurately predict the observed behaviour. Finite element (FE) updating method can be employed to fit the numerical models through the observed model. This paper proposes a new method to predict the random vibration of train-track-bridge system under earthquakes based on Hamiltonian Monte Carlo (HMC) method. The system identification is performed based on data recorded in situ. FE model is calibrated by minimizing the difference between the FE results and the natural frequencies of a real train-bridge coupled system. Naïve stochastic gradient descent is introduced to optimize the fitting process, avoiding over fitting and under fitting performance. The correlation matrix is built to calculate the correlation score between the measured and the HMC models. Based on above framework, results show that the HMC method has great effectiveness and accuracy with comparisons to the Monte Carlo method (MCM) and the popular probability density evolution method (PDEM). Moreover, the roles of bridge random parameters, track irregularities, and the seismic actions on the random responses are comprehensively investigated. Finally, the updating coefficients reduce the errors to less than 10%.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Figures

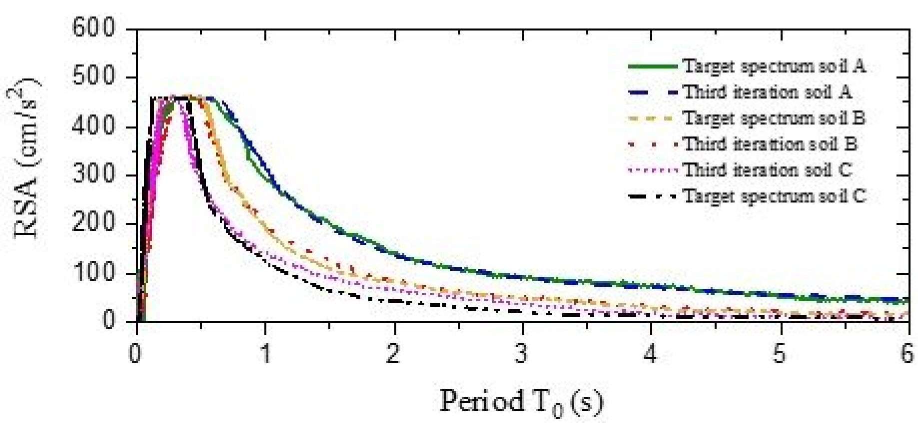

Figure 1

Acceleration average response spectrum

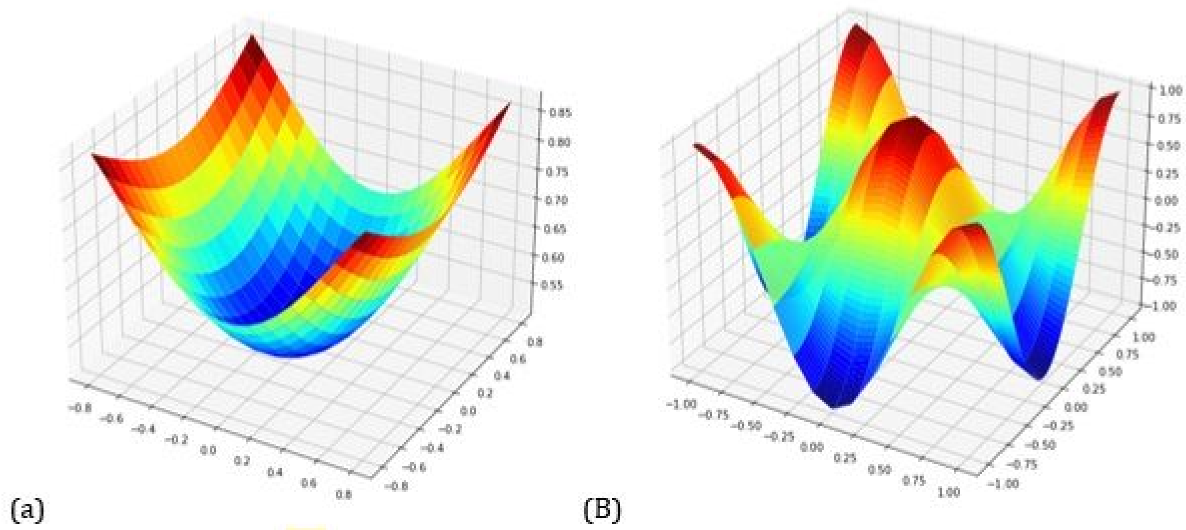

Figure 2

(a) Gradient descent (b) Stochastic gradient

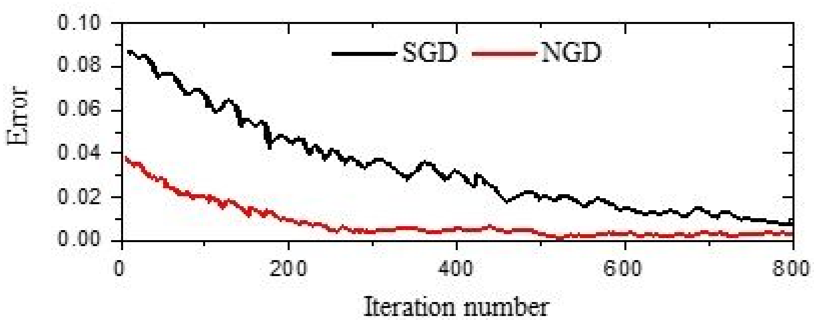

Figure 3

Error vs iterations for the SGD and NGD

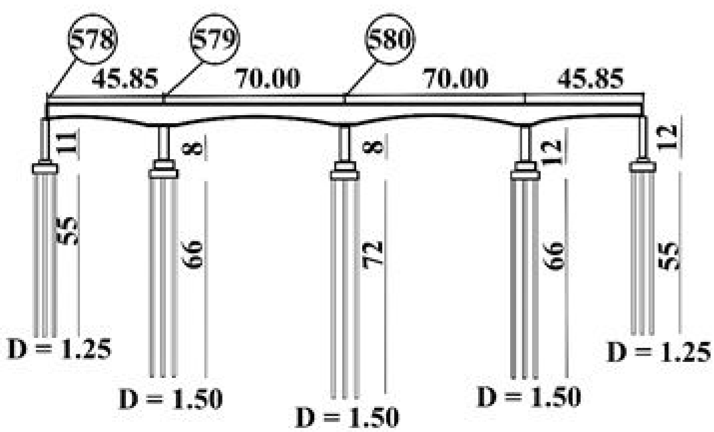

Figure 4

Side view of Simply supported bridge model (m)

Figure 5

Image of Beijing-Tianjin intercity railway bridge (side view)

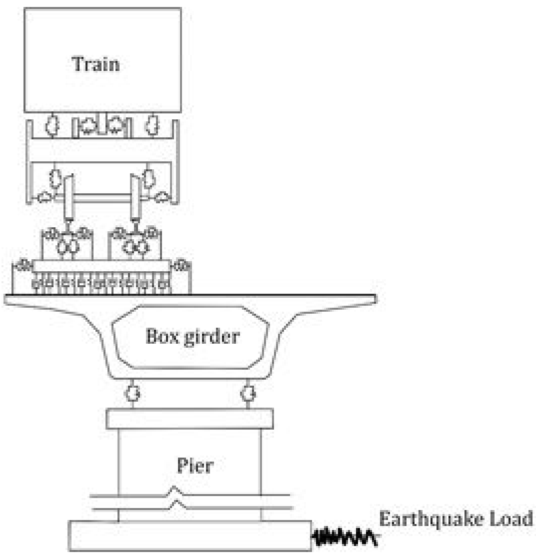

Figure 6

Train-track-bridge model with a seismic load

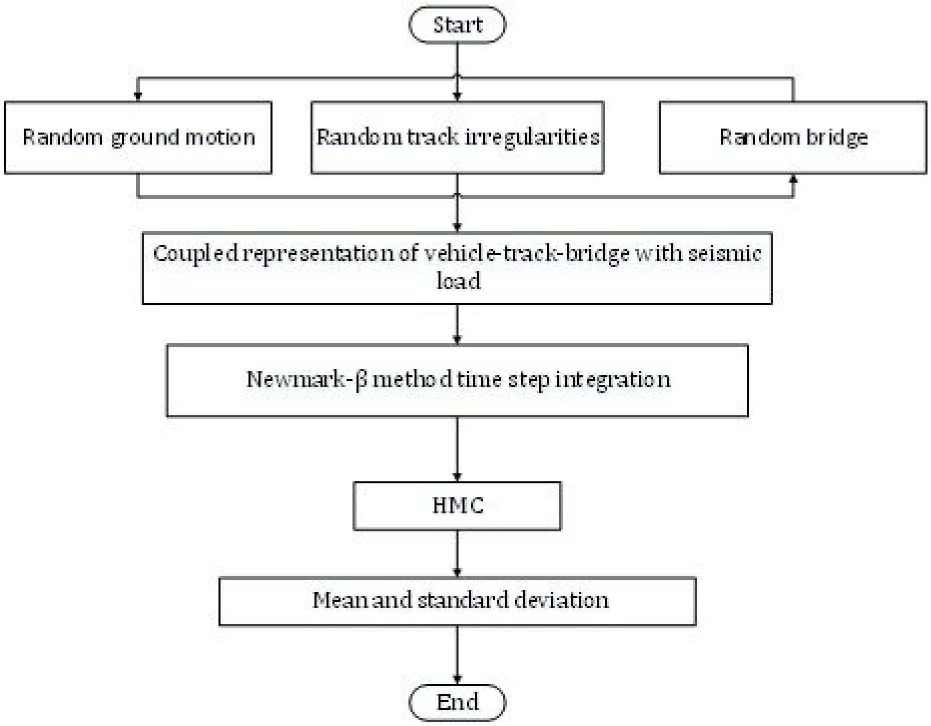

Figure 7

Flow chart for the solution of HMC for VTB random vibration affected to the earthquake

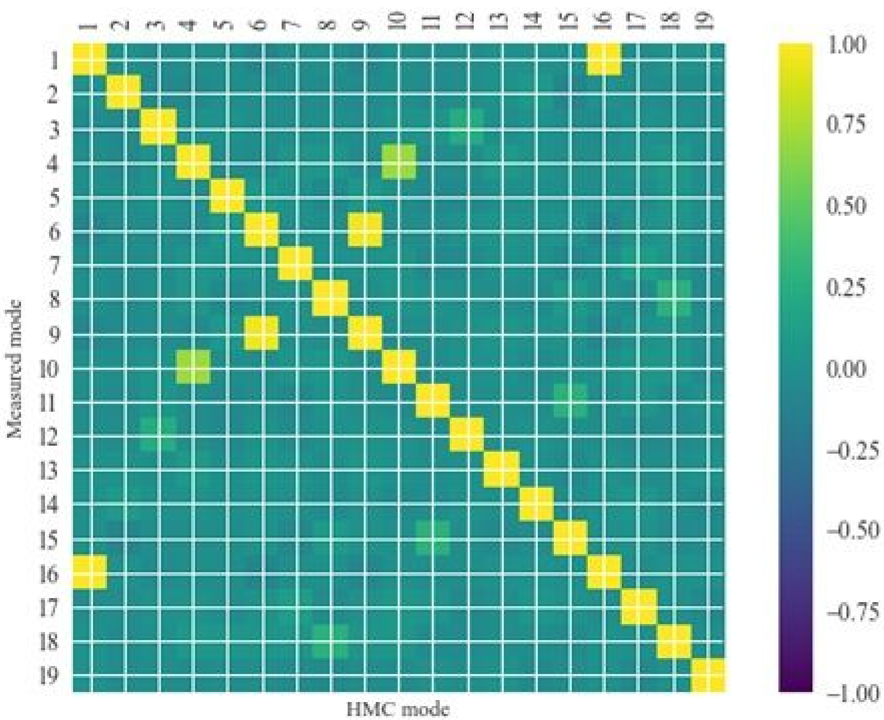

Figure 8

Correlation between the HMC and measured modes

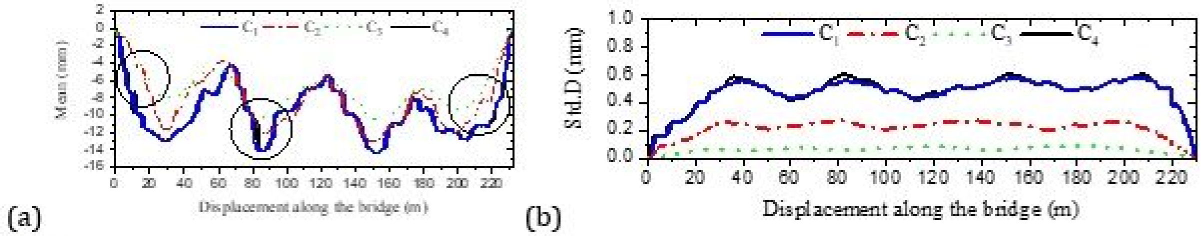

Fig 13. Vertical displacement at the bridge mid-span ((a) Mean; (b) Standard deviation) V=400km/h)

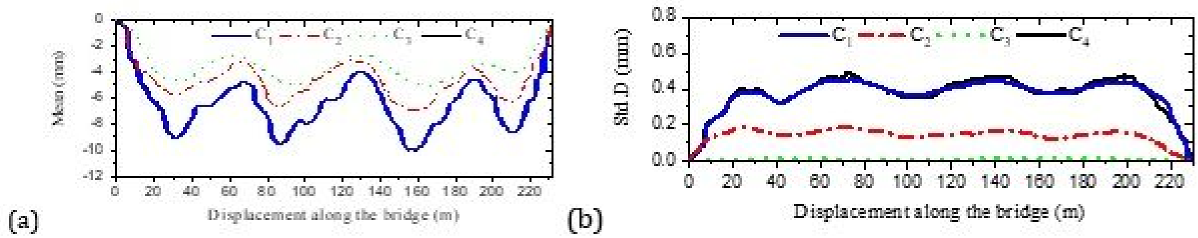

Figure 9

Vertical displacement at the bridge mid-span ((a) Mean; (b) Standard deviation) V=300km/h)

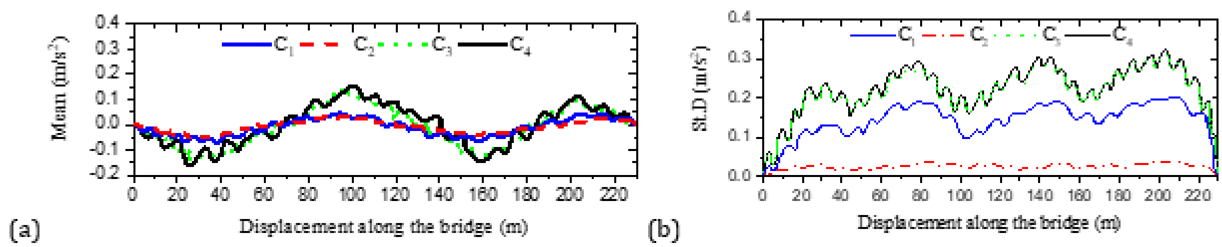

Figure 10

Lateral acceleration at the bridge mid-span ((a) Mean; (b) Standard deviation) V=300km)

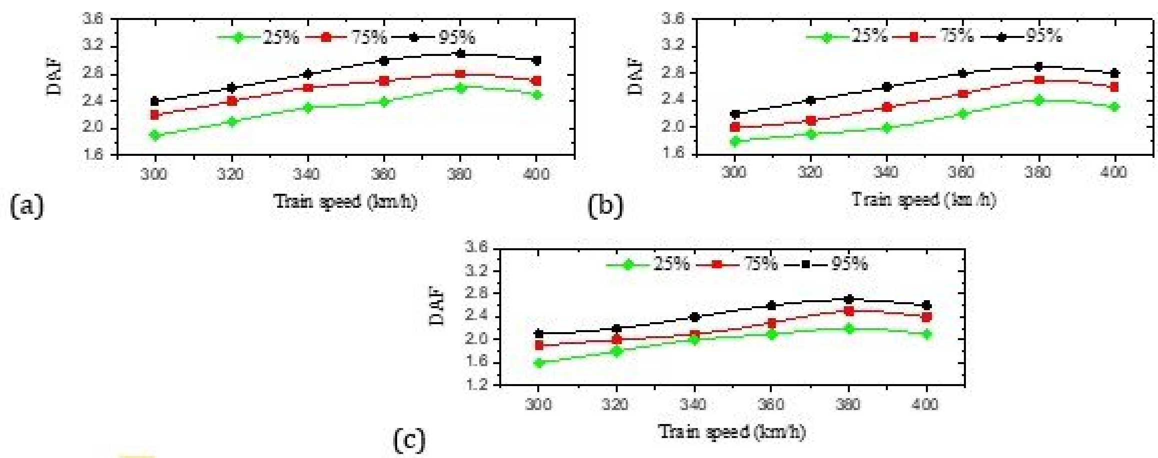

Figure 11

DAF of the lateral acceleration according to the soil type ((a) Soft soil; (b) Stiff soil; (c) Hard soil)

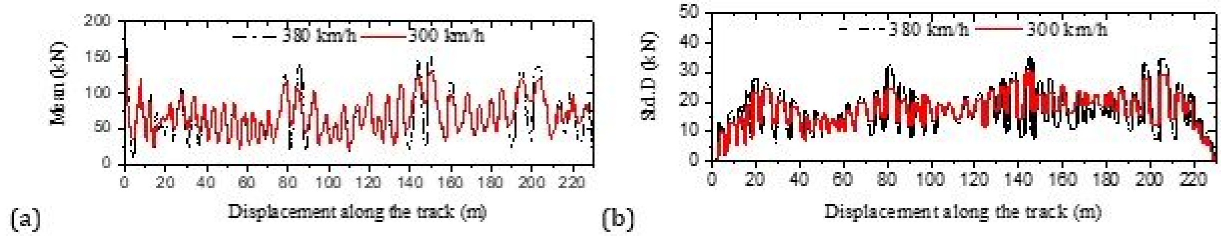

Figure 12

Soft soil vertical wheel-rail force ((a) Mean; (b) Standard deviation) Case 1

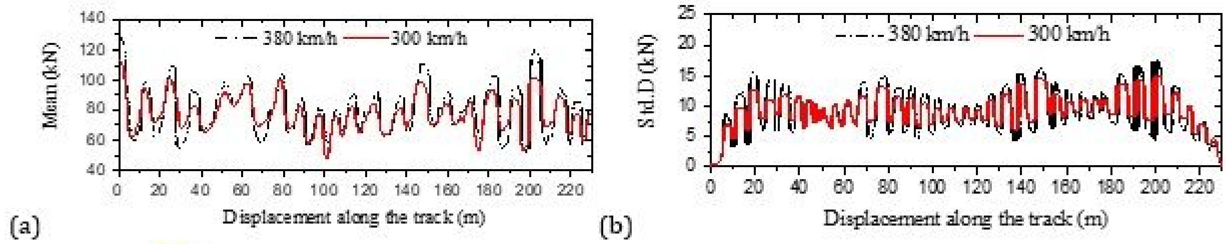

Figure 13

Soft soil vertical wheel-rail force ((a) Mean; (b) Standard deviation) case 2