

Generation of 3D-Digital Indian Public Road Profile Database and Its Application for Vehicle Development through Road-Vehicle Interaction Study

Prashant Pawar, Omkar Joshi, and Mangesh Saraf
Automotive Research Association of India

ABSTRACT

Design of vehicle for targeted customer usage is one of the key steps during vehicle development process. Due to globalization, most of vehicles, aggregates, components are being designed for global market considering worldwide load spectrum. Generally for doing this the vehicle response is being measured for different markets but this process is very time consuming. Also for getting these vehicle dependent parameters, exercises need to be repeated on each type/class of vehicle. So there is a need to have a robust procedure, tools which will helps OEM's to predict the loads, vehicle response for different market segments at an early stage of vehicle development program using the inputs which are vehicle independent. The solution for this could be to use vehicle independent input such as digitized road profiles (2D or 3D) of target customer markets in combination with proper MBD simulation tools.

This paper discuss about methodology used for generation of the 3D digital Indian road profile database and its applications in vehicle development. The paper elaborates on the methodology , process developed for measurement and the generation of vehicle independent 3D (X-Y-Z grid) digital road profile database (in .CRG/.RGR format) of typical Indian roads using LiDAR (Light Detection And Ranging) based laser sensors. Also various features of 3D public road profiles and its effect on vehicle response through Multi Body Dynamics (MBD) simulation are studied. The different applications of generated public 3D road profile database for vehicle design development are also discussed.

KEYWORDS: Durability, 3D road Profile, Virtual simulation, Road Vehicle Interaction Analysis

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INTRODUCTION

Road is primary source of vehicle vibration hence understanding of the road profile underlying the vehicle is important during design and development phase. ARAI has been working in the field of road profiling research projects since 2007[1]. In year 2007-08, ARAI has established the facilities for measurement of 2D longitudinal profiles of public roads and various test tracks and has carried out work of measurement of 2D Indian public road profile and studied it's effect on vehicle durability and ride. It was proved that the measured longitudinal profiles have been used effectively for predication of vehicle response in vertical direction with acceptable accuracy level [1]. To develop a concept of using vehicle independent inputs for vehicle ride-comfort and durability evaluation, ARAI is continuously working on development of different tools and has generated International Road Roughness (IRI) database comprising for length of 10,000 km Indian Roads. Current work is extension there search work.

Conventional vehicle development process comprises of the vehicle benchmarking, target setting, designing, prototype/mule vehicle manufacturing, road load data measurement and Lab testing

(component + full vehicle). Due to this vehicle loads and performance will be evaluated in later phase of product development. If any modifications are done on existing vehicle then entire development cycle needs to be repeated. This process is time consuming and high cost is involved in it. Current furious market competition and customer demand for variants of vehicle made OEMs to shorten their product development time and cost of vehicle development without compromising on the vehicle performance in terms of handling, ride-comfort, and durability etc. Hence OEM's are relying on CAE / Multi body simulation tools for prediction of vehicle ride-comfort, durability development of active system (Active Body control, Electronic assist power steering etc.), and drive file generation. Main component of vehicle simulation are vehicle model, road model, and tire model.

Tire force generation is governed by the shear stress and normal pressure distribution [2]. It is not uniform during rolling of tire on road irregularity. [2]. Now a day's, accurate prediction of the tire contact patch pressure distribution and its effect on tire forces prediction

become possible due to highly advanced tire model like FTire™ by Dr. Gipser [3]. Due to the tire model accuracy up to 150 Hz [3] prediction of vehicle ride-comfort and durability load become possible.

To increase quality and reliability of simulation, 3D representation of the road profile is desirable as forces introduced with passage of unevenness and obstacle diagonal to the driving direction can be represented by 3D road profiles. 3D representation of road profiles is needed for vRLDA [4] where virtually predicted loads are used as basis for development of component, subsystem and vehicle level durability for better accuracy. Addition to that 3D representation of road is required for applications like to study of handling behaviour of vehicle on road, to study effect of tire width on vehicle response, and for better prediction of vehicle dynamics, noise and vibration induced.[5] Moreover development of the market load spectrum & control strategy of active system requires the understanding of the public road profiles hence in order to take the advantage of simulation upcoming technologies in the vehicle development ARAI undertook project of measurement of 3D Indian public road profiles.

At first some basics of 3D road profile and standard file formats are discussed in brief. The second part of paper discusses work carried by ARAI in 3D Indian public road profile database generation. In third part, features of the digitized 3D Indian public road profiles are given. Comparison between vehicle loads predicted using 3D road profiles and experimentally measured road load is presented. At the end of the paper, various upcoming technologies/applications where the 3D road profiles database generated can be used are discussed.

3D ROAD PROFILE DATA FORMAT

3D road profile contains information of x-y-z co-ordinate. 3D digitized road profile of length 1 km contains around millions of data points in it. Handling of such a large data points in raw format co-ordinate format is inefficient and requires high computational capacity to run MBD simulation.

Various standard file formats namely, triangulation, Curved Regular Grid (CRG) and Regular Grid Road (RGR) are available to define digital 3D road profile data. Among the mentioned 3D road profile file format CRG and RGR file format are more popular and are widely accepted for simulation.

Curved Regular Grid Road (CRG)

Open CRG File format was developed by German OEM Daimler [6] and made public as OpenCRG™ in year 2005[7]. In this road model, road profile is specified by (curved) reference line, and a regular elevation grid, as shown in Figure 1.[8] Reference line defined by start, end location and heading angles. Optionally slope and hilliness value can be assigned to reference line.[8] Value of the grid data point i.e. z elevation of road profile is stored in array. Columns of the array contains the longitudinal elevation profile (i.e. along the direction of the reference line) and row contains the transverse road profile (i.e. perpendicular to centreline)

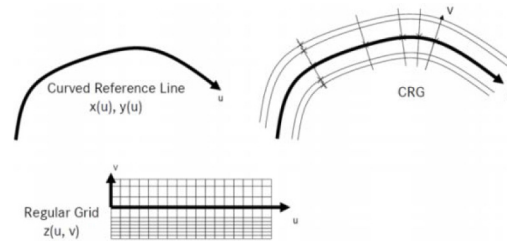


Figure 1. Curved Regular Grid Road profile [8]

Regular Grid Road (RGR)

Regular Grid Road (RGR) format is proprietary format of cosin™ software. In this file format the data points are equidistantly spaced both in x- and y-direction and only z values will be stored. Concept of RGR file is as shown in Figure 2. Curvilinear 3D road profile will be defined by additional centreline. This file format is efficient in computational effort and accuracy of the simulation. [9]

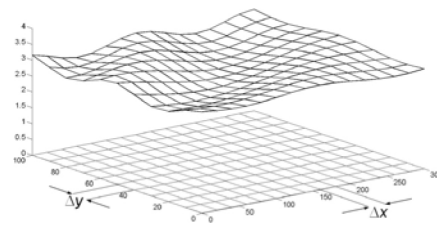


Figure 2. Concept of Regular Grid File format [9]

GENERATION OF 3D - DIGITAL INDIAN PUBLIC ROAD PROFILE DATABASE

Figure 3 shows the methodology adopted for generation of the 3D road profile database

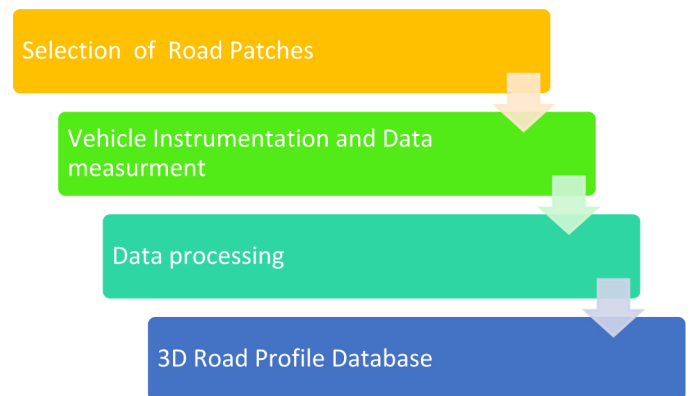


Figure 3. Work Flow adopted for digitization of the Indian Public road profiles

Selection of Route for Road Profile Scanning

Selection of the public roads/route for generation 3D road profile measurement was the crucial part of the project. Routes were finalized based on actual usage pattern of identified vehicle segment. viz. passenger car, Sport Utility Vehicle (SUV), Multi Utility Vehicle (MPV), Light Commercial Vehicle (LCV), Heavy Commercial Vehicle (HCV). Based on the earlier experience of the road profiling [1] and survey India [10] routes were selected to cover wide spread of

Indian terrain conditions namely, State Highway (SH), National Highway (NH), Express Highway (EX), City (CT), Mountain pass roads (GH), Village Road (VR) and Rough Road (RR).

Vehicle Instrumentation and 3D-Road Profile Data Measurement

3D Road Profiling System

The main components of the system are as follows

- LiDAR scanner
- Laser gyro
- Positioning System with base station
- Digital Camera
- Measurement PC's for the vehicle and power supply

Among different available techniques and sensor system, the road scanning with Light Detection and Ranging (LiDAR) technique along with laser based gyro was used. The ARAI measurement vehicle instrumented with 3D Road profile scanning system is shown in Figure 4. All scanned raw data was stored as a point cloud format.



Figure 4. 3D Road scanning system fitted on ARAI test vehicle



Figure 5. ARAI 3D road profile measurement vehicle on different routes

Data Processing

Data processing of raw point cloud data consists of two stages -

1. Correction of raw point cloud data to get vehicle independent road profiles
2. Conversion of the corrected cloud data to CRG file format

Correction of Raw Point Cloud Data to Get Vehicle Independent Road Profiles

As the laser scanner was mounted on the vehicle, during the scanning the vehicle movement affects the scan profiles of test track. To compensate for these motions and to make the measured profiles independent of the vehicle, cloud data (roughly 100000 raw points in section of about 5 m data) has to be corrected. The precise vehicle motions calculated using laser based gyro is used to remove the vehicle dynamics effect from measured point cloud data. This was done with special post processing software

As shown in Figure 6, the first red profile (raw point cloud) is much displaced point cloud due to rolling and pitching movement of the instrumented vehicle caused by severity of torture track. Second image shows the overlay comparison of corrected (grey scale) profile with that raw scan profile (red) and it was observed that selected hardware with combination of Laser based gyro effectively correct the raw scan by removing the vehicle vibration effects.

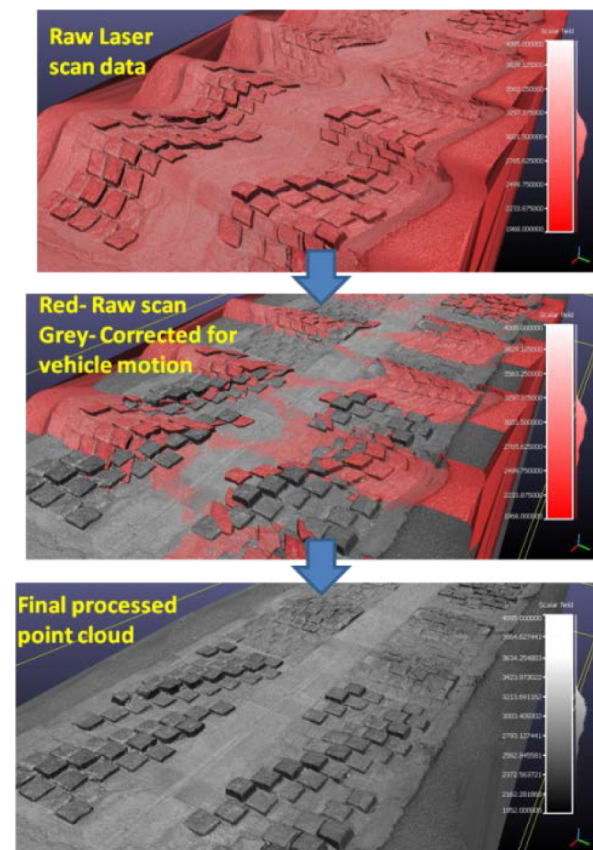


Figure 6. Results ARAI test track (comparison with and without correction for vehicle motion)