

Analysis, Creation and Extraction of Three-Dimensional Road Profiles Using Open CRG Tool

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ABSTRACT

In vehicle systems dynamics, there is wide applications of simulation of vehicles on road surfaces. These simulation applications are related to vehicle handling, ride comfort, and durability. For accurate prediction of results, there is need for a reliable and efficient road representations. The efficient representation of road surface profiles is to represent them in three-dimensional space. This is made possible by the CRG (Curved Regular Grid) approach. OpenCRG is a complete open source project including a tool suite for the creation, modification and evaluation of road surfaces. Its objective is to standardized detailed road surface description and it may be used for applications like tire models, vibrations or driving simulation. The Matlab tool suite of OpenCRG provides powerful modification or creation tools and allows to visualize the 3D road data representation. The current research focuses on basic concepts of OpenCRG and its Matlab environment. The creation of simple virtual three dimensional roads has been programmed. Also the extraction of longitudinal road profiles from three dimensional CRG format is researched.

Keywords— OpenCRG, Matlab, Road/Terrain Profile, Belgian Block.

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I. INTRODUCTION

Open CRG is a complete open source project including a tool suite for the creation, modification and evaluation of road surfaces, and an open file format specification CRG (curved regular grid). Its objective is to standardized detailed road surface description and it may be used for applications like tire models, vibrations or driving simulation. OpenCRG is developed by Daimler AG and VIRES GmbH in 2008. The research group AK 6.1.3 of the German OEMs Audi, BMW, Daimler, Porsche and Volkswagen supports a common open source project and make CRG available to everybody.

The Matlab tool suite provides powerful modification or creation tools and allows to visualize the 3D road data representation. The earlier name of OpenCRG is a format called CRG (curved regular grid) which has been used internally for several years by Daimler AG. An entire suite of Matlab and FORTRAN tools had been developed for the handling, evaluation and generation of CRG data. The early

phase of the OpenCRG initiative is funded by a series of German automotive OEMs. The research group of the Audi, BMW, Daimler, Porsche and Volkswagen define the objectives of the OpenCRG. Since 2008, Daimler AG develops and refines OpenCRG in collaboration with VIRES GmbH, a simulation technology company.

In vehicle systems dynamics, there is wide and deep applications of simulation of vehicles on road surfaces. These simulation applications are related to vehicle handling, ride comfort, and durability. For accurate prediction of results, there is need for a reliable and efficient road representations. The efficient representation of road surface profiles is to represent them in three-dimensional space. This is made possible by the CRG (Curved Regular Grid) approach. Its objective is to standardized detailed road surface description and it may be used for applications like tire models, vibrations or driving simulation. The Matlab tool suite of OpenCRG provides powerful modification or creation tools and allows to visualize the 3D road data representation. The

roads has been programmed. Also the extraction of longitudinal road profiles from three dimensional CRG format is researched.

OpenCRG is a standardized efficient three-dimensional road profile data representation defined in base plane by its direction (heading and yaw angle). It is optionally complimented by hilliness (slope, inclination, grade) and cross slope (banking, roll camber, angle).

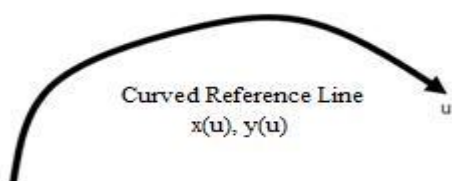
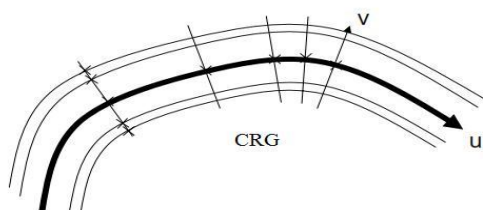


Figure 1 shows the Curved Reference Line (Chord Line, Track) defined in base plane by direction (heading, yaw angle). This line is a representation of overview map of road in denoted in XY axis.



A. Terminology Related to OpenCRG

- (x0, y0) inertial coordinates for reference line
origin (default (0, 0))

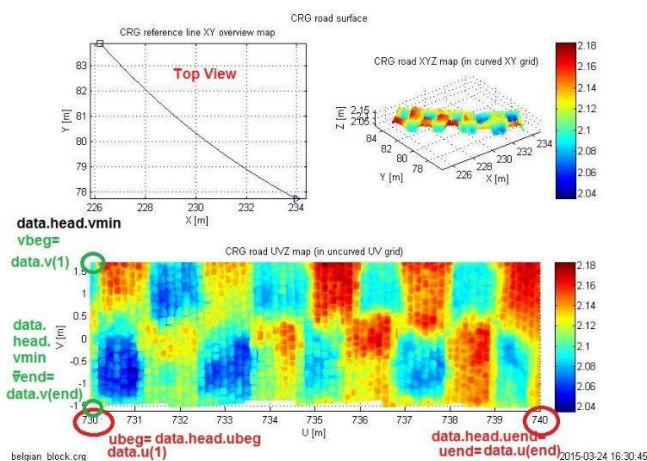


Figure 4 shows the CRG road surface of Belgian Block road. XYZ axes represents the road in curved XY grid with Z axis as elevation. CRG reference line is represented in XY overview map. UVZ map denotes the road in uncurved UV grid with Z axis as elevation.

III. CREATION OF THREE DIMENSIONAL ROAD PROFILE

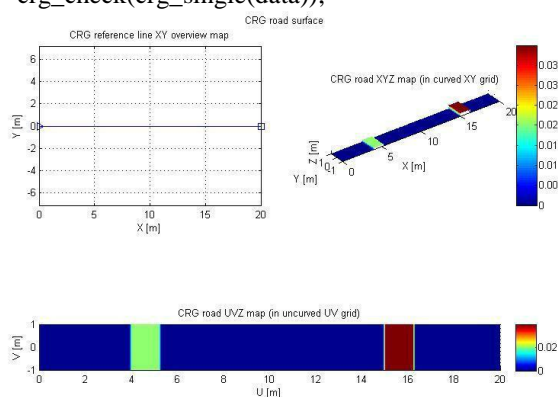
To understand the basic concepts behind OpenCRG, following are some Matlab script programs formulated. These programs helps to create simple three dimensional road profiles.

A. Case 1 – Road with two bumps

```
data = struct; data.u = 20;
data.v = 1
data.z(201,21)=0;

data.z( 41: 53, :)=0.02;
data.z(151:163, :)=0.04; crg =
crg_check(data);
```

```
crg = crg_check(crg_single(data));
```



<unknown CRG file name>

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Figure 5 CRG Road Surface Case 1 – Road with two bumps

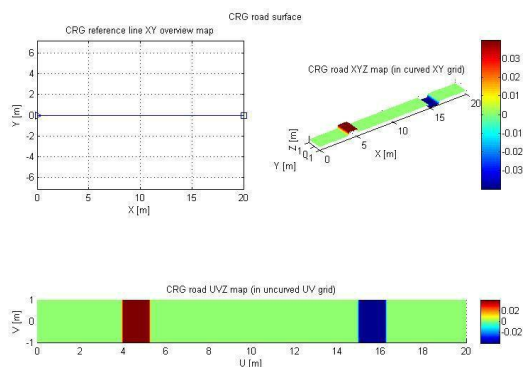
B. Case 2 – Road with one bump and one hitch (pothole)

```
data = struct; data.u = 20;
data.v = 2; data.v()
data.z(201,21)=0;

data.z( 41: 53, :)=0.04;
data.z(151:163, :)=0.04; crg =
crg_check(data);
```

```
crg = crg_check(crg_single(data));
crg_show(crg);
```

```
crg
```



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Figure 6 CRG Road Surface Case 2 – Road with one bump and one hitch (pothole)

C. Case 3 – Road with curvature

```
data = struct; data.u = 20;
data.v = 2; data.v()
data.z(201,21)=0;

data.z( 41: 53, :)=0.04; data.z(151:163, :)=
0.04; data.p = cos([1:200]/200 *2*pi);
```

```
crg = crg_check(crg_single(data));
crg_show(crg);
```

```
crg
```

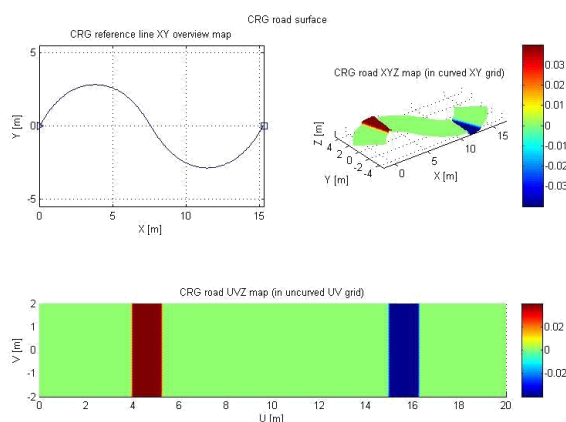


Figure 7 CRG Road Surface Case 3 – Road with curvature

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IV. EXTRACTION OF LONGITUDINAL ROAD PROFILES FROM THREE DIMENSIONAL CRG ROAD FORMAT

Measured data of three dimensional road profiles is been directly obtained and stored in .crg format in a computer of measurement vehicle. This process is been developed by Daimler AG and VIRES GmbH in 2008. The research group AK 6.1.3 of the German OEMs Audi, BMW, Daimler, Porsche and Volkswagen supports a common open source project to make CRG available to everybody.

CRG data obtained is in a complied format. To use data from CRG as per one's requirement, there is a complex

Matlab suite. This involves around 80 commands which are difficult to understand for beginners. Using this tool suite, a program for the extraction of longitudinal profiles is developed. Sample CRG file extracted is Belgian Block pavement.

Initialization OpenCRG environment in Matlab

```
Clear all
clc
```

```
OpenCRGDIR='C:\Users\RHB\Desktop\Project\...
OpenCRG';
```

```

cd(OpenCRGDIR)
run([OpenCRGDIR, '\OpenCRG.1.0.6\matlab/...
crg_init']);
cd([OpenCRGDIR, '\OpenCRG.1.0.6\temp'])

```

D. CRG filename input

```
crg_filename='belgian_block.crg';
```

E. Read crg file before showing it and show it

```

crg=crg_read(crg_filename);
data=crg_show(crg);

```

F. Various variables related to u (data.u) & v (data.v)

```

ubeg=data.head.ubeg;
uend=data.head.uend;

uinc=data.head.uinc; nu=round((uend-
ubeg)/uinc)+1; vmin=data.head.vmin;
vmax=data.head.vmax;
vinc=data.head.vinc; nv=round((vmax-
vmin)/vinc)+1;

```

G. Extraction of longitudinal road profile from crg file

Specify 'longitudinal increment (uinc_cut)' or 'number of longitudinal points (nu_cut)' and specify 'lateral increment (vinc_cut)' or 'number of lateral points (nv_cut)'

1) Case 1 uinc_cut & vinc_cut are specified:

```

uinc_cut=      0.01;
vinc_cut= 0.1;

puv= [ubeg:uinc_cut:uend]';    v=
[vmin:vinc_cut:vmax];

for      i=1:1:numel(v);
    puв( :,2)=v(i);

    elevation=crg_eval_uv2z(data,puv);
    Z{1,i}=elevation; plot(puv(:,1),elevation);

    hold all
end

```

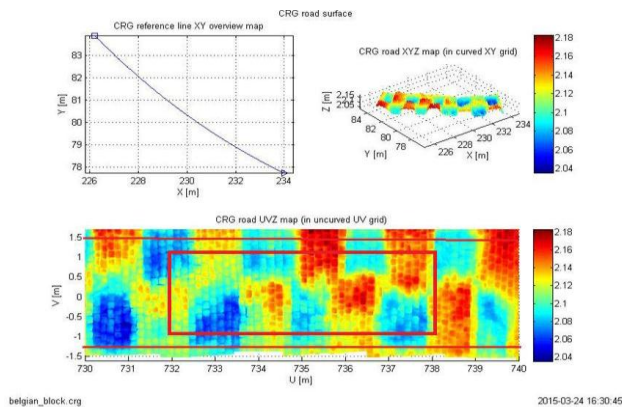


Figure 8 Extraction of Longitudinal Road Profiles from Three Dimensional CRG Road Format

Figure 8 is the CRG representation of Belgian Block pavement. The same figure also explains portion to be extracted (red lines). This extracted profiles can be further analysed for International Roughness Index, Guassianity, Stationarity, etc. Hence the main aim of this research was to provide authentic longitudinal road profiles data for the analysis of roughness indices, ride characteristics of vehicle running on different road profiles.

Following is an algorithm and Matlab program to extract longitudinal road profiles from three dimensional crg road format.

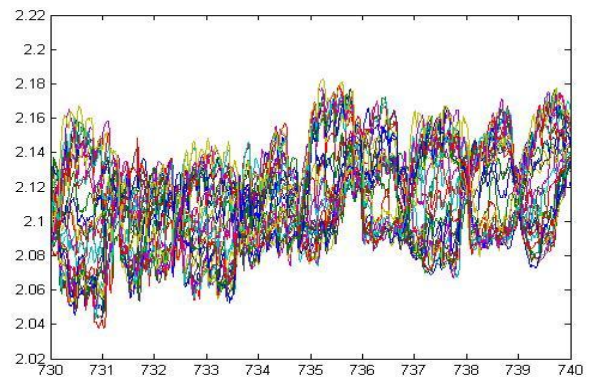


Figure 9 Extracted Longitudinal Road Profile: uinc_cut & vinc_cut are specified

- 2) Case 2 nu_Cut & Nv_Cut are Specified:
 $uinc_cut = \text{round}((uend - ubeg) / (nu_cut - 1));$
 $vinc_cut = \text{round}((vmin - vmax) / (nv_cut - 1));$

But, uinc_cut & vinc_cut must be a multiple of CRG increment 1.000000e-03 otherwise it gives error. Hence utmost care should be taken while using this case

- 3) Case 3 only a portion of 3D road is to be extracted:

Specify ubeg_cut, uend_cut, vmin_cut, vmax_cut with uinc_cut & vinc_cut are specified.

```
ubeg_cut=732;
uend_cut=738;
vmin_cut=-1;
vmax_cut=1;

uinc_cut= 0.01;
vinc_cut= 0.1;

puv= [ubeg_cut:uinc_cut:uend_cut]'; v=
[vmin_cut:vinc_cut:vmax_cut];

crg_show_road_uv2surface(data,ubeg_cut:...
uend_cut,vmin_cut:vmax_cut);
figure

for i=1:1:numel(v);
    puv(:,2)=v(i);

    elevation=crg_eval_uv2z(data,puv);
    Z{1,i}=elevation; plot(puv(:,1),elevation);

    hold all
end
```

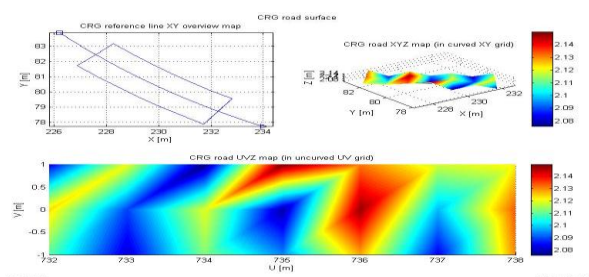


Figure 10 Extracted Portion of Road Surface - Case 3

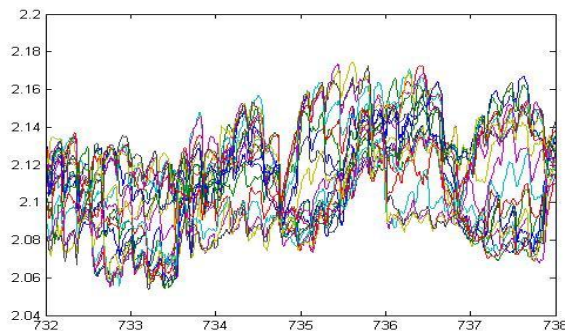


Figure 11 Longitudinal Profiles of Extracted Portion of Road Surface -

Case 3

H. Formatting Outputs to an Excel

```
File z=cell2mat(Z);
elevation_data_z=[v;z];
longitudinal_cut_u=[00;puv(:,1)];
elevation_data_z=[longitudinal_cut_u,...

elevation_data_z];
xlswrite('elevation_data_z',elevation_...

data_z)
```

V. CONCLUSIONS

In the current research work, OpenCRG is been introduced, which is a complete open source project including a tool suite for the creation, modification and evaluation of road surfaces. Idea behind OpenCRG concept is studied. Terminology related to OpenCRG is studied and shown graphically. Furthermore, the Matlab script programs are written to create different three dimensional virtual road. This includes road with two bumps, road with one bump and one pothole and road with curvature. This creation of roads has simplified the understanding of newly introduced OpenCRG concept. In the last section of research work, procedure for extraction of longitudinal road profiles from the three dimensional CRG format is elaborated. It includes selection of a particular CRG road file and then its extraction into longitudinal road profiles.

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