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# Modelling of roads for simulation

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- ❑ Since 1972 Consultant: Vibrations, Structural Dynamics, EMA
- ❑ ISO/TC 108. Modal Analysis, Shock Response Spectrum
- ❑ IEC /TC 104. Mechanical Conditions, S&V Test Standards
- ❑ Professor Mechanical Engineering, Non-Linear Mechanical systems
- ❑ Supervising PhD students. Beihang University

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- ❑ Chinese project, funded by NSFC
- ❑ “Self-driving vehicles on bad roads”
- ❑ Virtual test tracks for simulation
- ❑ Typical test track elements
- ❑ Test Track Definition File, TTDF
- ❑ ASCII file, each line defined a test track element

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A student found a lot of simulation models

- ❑ Speed bumps
- ❑ Washboard
- ❑ Pebble stone
- ❑ Potholes
- ❑ Etc, etc

One thing missing in real test tracks is long parts of common roads.

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We were lacking large amounts of high-resolution road profile data, laser measurements.

I contacted my friends in Tashkent, Uzbekistan


How about trading one-week seminars and road data?

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Ok, but make it two weeks! Then I bring my wife!

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And I was taken to a Classic Rock Concert.
Tashkent Concert Hall, Tashkent Symphonie Orchestra



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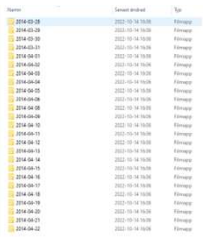
I got a lot of IRI data from Uzbekistan highways!





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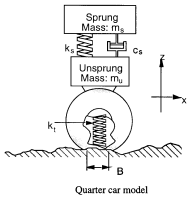
IRI is calculated on a Quarter Car Model, Golden car




Quarter car model

*Parameters used for The Golden Car"*

| | | |
|---|---|---|
| $c_s$ = | 6.0 * $m_s$ | [1/s] |
| $k_t$ = | 653.0 * $m_s$ | [1/s²] |
| $k_s$ = | 63.3 * $m_s$ | [1/s²] |
| $m_u$ = | 0.15 * $m_s$ | |

*All parameters can be normalized with $m_s$ = 1*



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IRI is defined as

**accumulated suspension stroke**

divided by **traveled distance**

with unit [inch/mile] or [mm/m]

The model is traveling the profile at 80 kmph



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Equations of motion

$$\left(M \cdot s^2 + C \cdot s + K\right) \cdot \begin{pmatrix} z_s \\ z_u \end{pmatrix} = \begin{pmatrix} 0 \\ k_t \cdot h \end{pmatrix}$$

$$d = \int_0^T \left| \dot{z}_s - \dot{z}_u \right| dt$$

$$IRI = \frac{1}{v \cdot T} \int_0^T \left| \dot{z}_s - \dot{z}_u \right| dt = \frac{1}{v} \cdot mean\left\{ \left| \dot{z}_s - \dot{z}_u \right| \right\}$$



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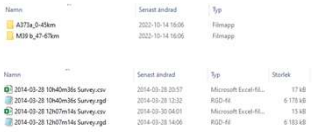
One example



RGD files are in Roughometer format
CSV files are standard Excel files
IRI measured in blocks of 100 meters



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I will use the first example, Survey1.csv
Converted to IRIDATA1.mat

```
load IRIDATA1
Header =
    'Survey date:,2014-03-28'
    'Survey time:,10:40:36   '
    'Road name:,A373a        '
    'From:,45 km             '
    'To:,0 km                '
```

```
Data(1:10,2)

    0.1000
    0.2000
    0.3000
    0.4000
    0.5000
    0.6000
    0.7000
    0.8000
    0.9000
    1.0000
```



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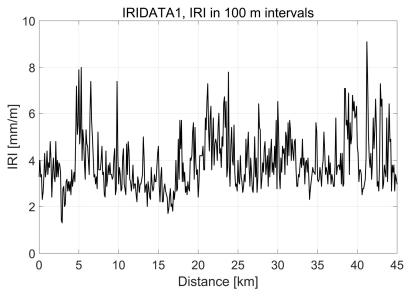




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How to get high-resolution road profile data for simulation? We may use models built on the ISO 8608 PSD model.

There are models suggested building on the ISO PSD and some IRI statistics.

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**Laplace distribution models for road topography and roughness**



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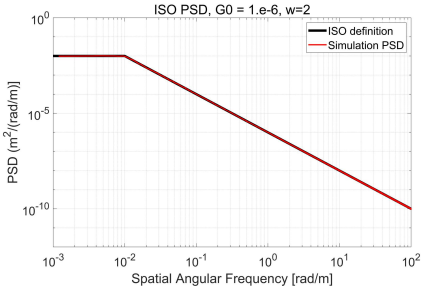




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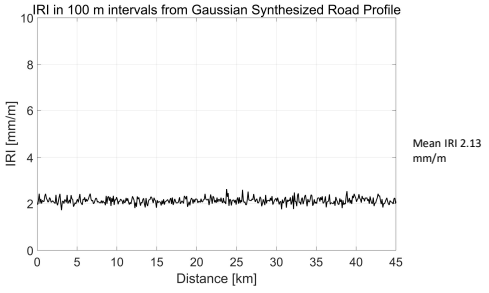




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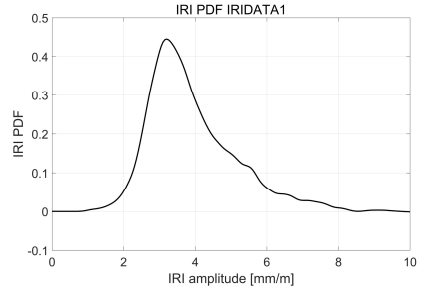




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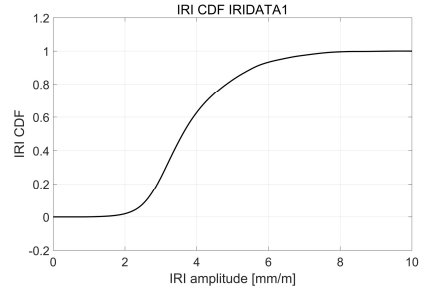


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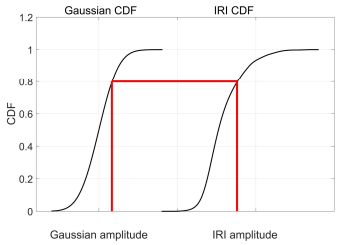
We make a low frequent Gaussian signal with high resolution, many samples per meter, and turn it into IRI statistics using CDF method.

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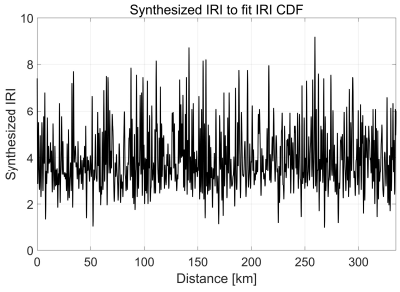


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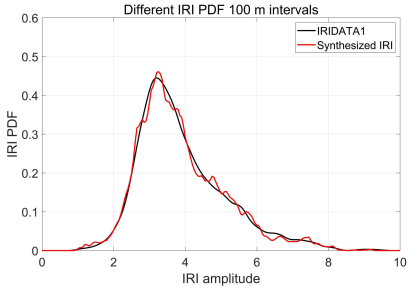


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Now multiply the IRI profile r(x) onto the Gaussian profile z(x) from ISO PSD.

$$zz(x) = r(x) \cdot z(x) / 2.13$$

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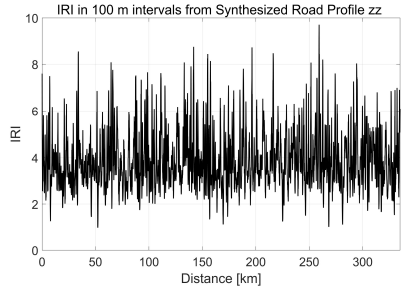


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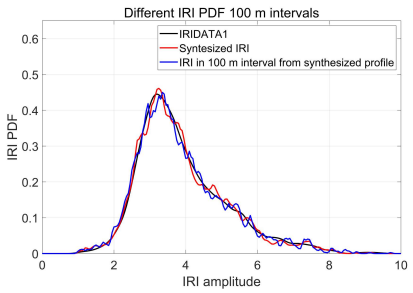


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To find out:

- ❑ What parameters for the ISO PSD?
- ❑ What parameters for the low frequent Gaussian signal?

Look at high-resolution laser road profile data.
Calculate IRI in blocks.
Test the suggested method.
Make improvements.

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Used MATLAB functions for free:

| | |
|---|---|
| *psdsynt* | makes a Gaussian signal from PSD definition |
| *IRIcalc* | calculates block IRI and total IRI from road profile |

*timeresv, framstat, resonances, linearresp, maketime*

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