Guidelines For Interpretation of Gorski Consulting Road Data From iPhone Testing - March 2014 Version

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A new webpage has been created on the Gorski Consulting website entitled "Road Data". It contains data obtained from road testing that was conducted by Gorski Consulting with multiple video cameras and an Apple iPhone. The sensors of the iPhone were used to create a data file of motions and accelerations experienced by the test vehicle during its travels through roads in the City of London and on highways in Southern Ontario.

The sites of the testing are sorted in the database by their geographical location. At the present time only three jurisdictions exist in the database:

City of London

Middlesex County

Lambton County

As more testing is performed other jurisdictions are expected to be added.

Roads within the "City of London" category include portions of Highway 401 even though this highway is actually governed by the Ontario Ministry of Transportation. Again, this is done to simplify our work rather than to imply that certain roads are the responsibility of one municipality or another.

In most instances the test vehicle was kept at a constant speed, where possible. At highway speeds this was accomplished by setting the "cruise" at the desired speed. In urban areas it was more difficult to maintain a constant speed however best efforts were made.

The most common segment of time reported in the database for which motion data was provided was 30 seconds. There was nothing significant about this, except that this length was convenient for creating individual charts of the data in an Excel program.

For those wanting to know the distance that was travelled by the test vehicle in those 30 seconds of reported data we offer the following advice. The distance travelled during this time can be derived from identifying the constant speed of the vehicle. So, for example, the test speed of 60 km/h can be divided by 3.6 to obtain the speed in "metres per second" which is 16.67. It is then possible to multiple the 16.67 by the number of seconds (30) and determine that the vehicle travelled (30 x 16.67) about 500 metres during the data collection. Of course, if the vehicle was travelling faster the distance travelled would be further and vise versa.

The most common sampling rate of the data collection was 32 Hertz, which means that there were 32 samples taken every second.

The vehicle used in this testing was a 2007 Buick Allure passenger car. It is expected that the use of other vehicles will produce altered results due to their differing suspensions and design. The effects of these vehicle differences will likely be explored in future testing.

Because of the large amount of data that was collected by the iPhone it became impractical to display it all in the database. Therefore it was necessary to select parameters that would be most useful in differentiating between the sites.

It was decided that the rate-of-change in the angle of the vehicle might best differentiate the sites. The app used to obtain this data stores the rates of lateral and longitudinal rotation in radians. Members of the public are often not used to working with radians and are more familiar with degrees. There are 57.3 degrees in one radian.

The iPhone senses the angle of the vehicle along its three axes, x, y and z. The X-axis is often described as a pole that punctures the side doors of a vehicle such that the vehicle then revolves around this pole. Similarly, the Y-axis is a pole that punctures the front and rear license plates and the vehicle rotates around that pole. Finally, the Z-axis is a pole that punctures the roof and floor of the vehicle so that the vehicle rotates around that pole.

Rotation around the Z-axis is a motion called "yaw" and this is the most common indicator of a vehicle's loss-of-control because it produces curved "yaw" tire marks on a road surface before it crashes. However we decided not to report this value because, by the time such yaw marks become visible on a roadway, it is almost guaranteed that most vehicles on public roads will be involved in a collision. In other words, there would to be little yaw rotation expected in the motion data during the normal travel performed by the test vehicle and it would be difficult to use this parameter to differentiate one road from another. For this reason only the lateral (rotation about the X axis) and longitudinal (rotation about the Y axis) motions of the test vehicle were reported in the database.

Because the test vehicle could rotate clockwise or counter-clockwise on any axis, the reported radian data alternated between positive and negative values and reporting an average of these values would not reveal the different magnitudes of motion in the test vehicle. Therefore the standard deviation of the rate-of-rotation was taken as the final value that would be displayed in the database. Thus when the standard deviation is high it indicates that, on average, the rate of rotation, whether clockwise or counter clockwise, is high and vise versa. So if the values displayed in the "Lateral Motion" or "Longitudinal Motion" are high it indicates that the magnitude of the vehicle's displacement from a "perfectly level" condition is also large and that the vehicle's interaction with the road surface is causing that motion.

The iPhone was placed close to the centre-of-gravity of the test vehicle so any stored data would reflect what was happening at the centre of the vehicle rather than at some periphery.

Recording of vehicle motion often occurred continuously over 20 minutes or more before the recording was paused, the file was sent by e-mail, and a new recording was begun. Yet only small segments of recording time were selected for inclusion in the present database, while a much greater amount remains available but not reported. One might wonder why all the recorded data was not reported as one continuous stream.

In these early investigations the focus was on selecting road segments that were straight and level. This was done so it could be demonstrated that the data collection was reliably documenting the difference between the roads. Mixing straight and level roads with roads that contain significant horizontal and vertical curves would confuse the comparison. As this work continues and more sites are added, and further analysis is conducted, it is expected that the concerns over the reliability of the data will be alleviated and it is expected that more segments with various horizontal and vertical curves will be included. Despite this comment, there are several sites in the database that contain factors beyond the straight and level.

For example, there are several records on the S-curve of Clarke Road in London Ontario that provide an indication of the effect of horizontal and vertical alignments.

Figure 1: View, looking southbound at the S-Curve of Clarke Road north of Fanshawe Park Road in London, Ontario, showing the horizontal and vertical alignments of the road.

There are also several records incorporating situations where the road surface was covered, or partially covered, by snow or ice. Interestingly, these show just how much disruption in the vehicle motion can occur when a hard crust of snow or ice is formed in an irregular fashion in the travel path of a vehicle's tires. The most extreme conditions of vehicle motion to date were documented on Mckenzie Avenue in London, Ontario where the road had not been plowed for an extended time and this caused a thick layer of hardened snow and ice that was rutted, as shown in Figure 2 below. The test vehicle travelled through this local road at speeds of just 20 km/h yet it registered the highest motion readings of all the sites to date.

Figure 2: View, looking west, along McKenzie Avenue in Old-South, London, Ontario, showing the deep ruts caused by unplowed snow that had been compressed into solid ice and snow on the road surface. This was the condition of the road at the time that the data was captured.

Similarly, though less severe, conditions were noted on Oil Springs Line, in Lambton County, where an irregular layer of hardened snow and ice existed mostly on the right portion of the westbound travel lane, as shown in Figure 3. The test vehicle's speed was reduced to just 30 to 40 km/h on this rural highway that had a maximum posted speed limit of 80 km/h, yet high values of motion of the test vehicle were registered.

The Lateral and Longitudinal Motion values have also been colour-coded in the database to provide a quicker recognition of which roads were found to be "good" or "bad". Good (low) values are coded in green, median quality roads are coded in black, and poor (high) values are coded in red. The coding categories were arbitrarily developed according to the following rules:

Figure 3: View, looking west, along Oil Springs Line showing the hardened snow and ice located on the right half of the westbound lane. This was the condition of the road at the time that the motion data was obtained with the test vehicle.

Green (Good) = Values of below 0.0200 radians per second.

Black (Median) = Values between 0.0200 and 0.0500 radians per second.

Red (Poor) = Values of 0.0500 or above, radians per second.

This preliminary categorization has been based on observing the small amount of road data that is presently available and this may change in the future.

At the bottom of each section of roads under a particular jurisdiction we have also included an average value for all the roads in that jurisdiction. For example these are the values for the three jurisdictions in the database:

City of London - Lateral Motion = 0.0428, Longitudinal Motion = 0.0373

Middlesex County - Lateral Motion = 0.0140, Longitudinal Motion = 0.0132

Lambton County - Lateral Motion = 0.0181, Longitudinal Motion = 0.0190

At present this has little meaning because of the small number of roads that have been documented to date. The data from Mckenzie Avenue, Oils Springs Line and

Sunningdale Road presently skew the average to make it appear that those jurisdictions contain poorer roads and this is likely not true. As the database becomes larger this average might be used as a guide to indicate what values of vehicle motion can be expected for larger groups of roads.

Overall, it is expected that the Lateral and Longitudinal Motion columns in the database will provide enough preliminary information about the condition of a road segment that those who would like further information will be motivated to request it. Beyond the additional data available from the iPhone, there was extensive video data that accompanied it. For example a video camera mounted beneath the front bumper of the test vehicle captured the condition of the road surface from just a few inches above it, as shown in Figures 4 and 5.

Figure 4: View, looking westbound, at the road surface of Sunningdale Road in London, Ontario, taken by the video camera located beneath the front bumper of the test vehicle.

Thus, not only is possible to know precisely what portion of a road caused a certain motion of the test vehicle, but that portion of the road can be seen from several video cameras mounted in the interior and on the exterior of the vehicle. There is also video documentation about any braking, throttle and steering applications that one might want to evaluate. Furthermore, arrangements can also be made to conduct laser scanning of the characteristics of a site if such is required.

Figure 5: View looking west near Highbury Ave and Wilton Grove Road, from the video camera mounted beneath the front bumper of the test vehicle.

As testing continues, and further analysis is conducted, it is likely that changes to the database will be made and further guidelines and explanations will be posted in future articles.

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