THE UNIVERSITY OF TEXAS AT ARLINGTON

Project Summary Report 0-4480-S

Project 0-4480: Developing a Methodology for Collecting Stop and Go Inertial Profile Measurements

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PROJECT SUMMARY REPORT

Collecting Stop-and-Go Inertial Profile Measurements: Summary Report

The Texas Department of Transportation (TxDOT) annually collects profile data over the state-maintained highway network. TxDOT uses the profile data to determine ride quality based on the present serviceability index (PSI). The indices determined are stored in the Pavement Management Information System (PMIS) database and are published in the PMIS reports prepared annually by the Materials and Pavements Section of the Construction Division. Inertial reference profilers, such as TxDOT's profilers, are adversely affected by stop-and-go (SAG) operations, common during PMIS data collections. When the profiler slows below 10 mph or comes to a complete stop, profile measurements are not valid. This situation causes the loss of ride data at intersections, in high traffic conditions, and in urban areas. During TxDOT research project 0-4480, a method was developed that minimizes the effects of SAG for the inertial profile measurements.

What We Did...

There are a number of factors that affect profile measurements using inertial reference profilers at slow speeds. For example, one major factor is the measurements from the accelerometer used for vehicle body vertical accelerations. The accelerometer provides a voltage proportional to the body acceleration. The accelerometer readings provide a measurement of the second derivative of the vehicle body with respect to time. As the profiler vehicle slows, the accelerations and associated voltages affecting the measurements become very small. If small but abrupt changes occur, such as the vehicle stopping and then starting forward, a vertical impulse component can occur. The voltage component can be significant when compared to the previous readings. This change in voltage affects the filtering done in the road profile computations and results in wide swings in the computed profile. The effect of SAG operation on profiles from one of the TxDOT profilers is illustrated in Figure 1. For this figure, the profiler is initially traveling at a speed of about 40 mph before slowing to a complete stop and then starting back up to the original speed.

Profile Attenuation

During initial startup, wide swings in the profile exist because of the high-pass filtering used to attenuate the low frequencies or long wave lengths. The distance required for settling varies but is related to the filter type and cutoff frequency. Since filtering is required for inertial reference profilers using accelerometer-based systems, methods focused on reducing the undesired side effects of this filtering. Either the filter characteristics need to be changed or attenuation applied to the profile at these times to prevent the wide swings.

Profile attenuation can be applied in several places in profile data collection, either to the individual sensor readings before the profile computation

module in WinTK (The University of Texas at Arlington [UTA] profiler server software) or applied in the profile module during filtering. To address attenuation methods, the SAG question for the profiler had three main issues that needed to be addressed. The first was how to minimize the effect of the filter swing when the vehicle starts to slow down. The second issue was to identify the actual speed when the SAG problem occurs. Finally, at what speed or time does the profile computation procedure recover from the SAG effects?

A 'SAG Window' was defined as the portion of time and distance where the profile is adversely affected by the SAG actions and during which corrective action is to be applied. The system uses a distance signal, where each pulse of that signal represents a length the vehicle has traveled. The profiler uses a state machine that recognizes the individual pulses of the distance signal, where the positive-going part of the signal is used to distinguish between the distance pulses. The time it takes to complete the distance pulse is related to the vehicle speed. Variables are used in the state machine during the real-time sensor data acquisition, handling the various sensor signals used in computing profiles as they are sampled with respect to time. One of these variables is the Time Factor (TF), which is used to indicate the number (or frequency) of time samples obtained over a specific distance interval.

Since TF is the measure of the number of sensor readings received per each distance signal, it is proportional to the inverse of the speed of the vehicle. This value was observed, recorded, and used to indicate where in the time of a data collection that the SAG Window begins and ends. Figure 2 illustrates a typical relationship observed for the time factor as a function of speed. As may be observed from this figure, the faster the speed, the smaller the time factor or TF becomes.

A number of techniques were tried and tested in finding the SAG Window. Within this window, various attenuation methods were applied to the profile or sensor values during the window period. None of the attenuation methods seems to work for all cases. However, some success was noted with controlling the TF variable. That experiment involved using the clock and timer mode of the profiler in order to keep the amplitude of the profile in the correct range. For this case, distance pulses are sent to the profiler in accordance with a separate time signal. The profile would always be within the correct range although the location of the data would shift. For this

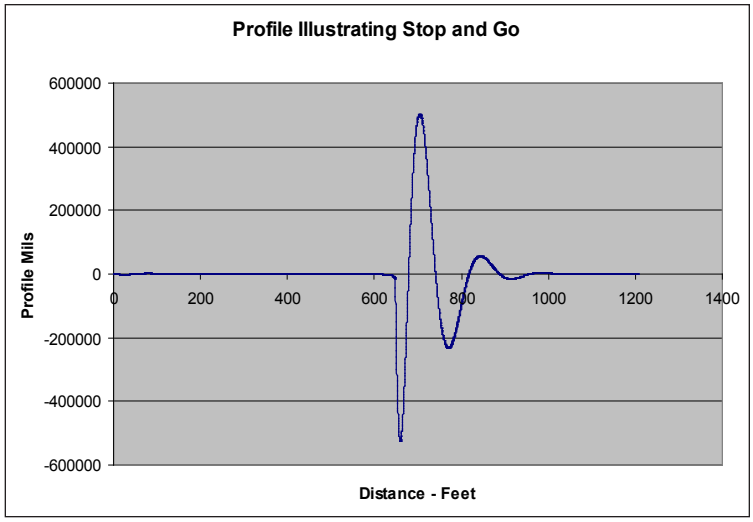

Figure 1. Effects of Stop-and-Go on Profile by TxDOT Profiler.

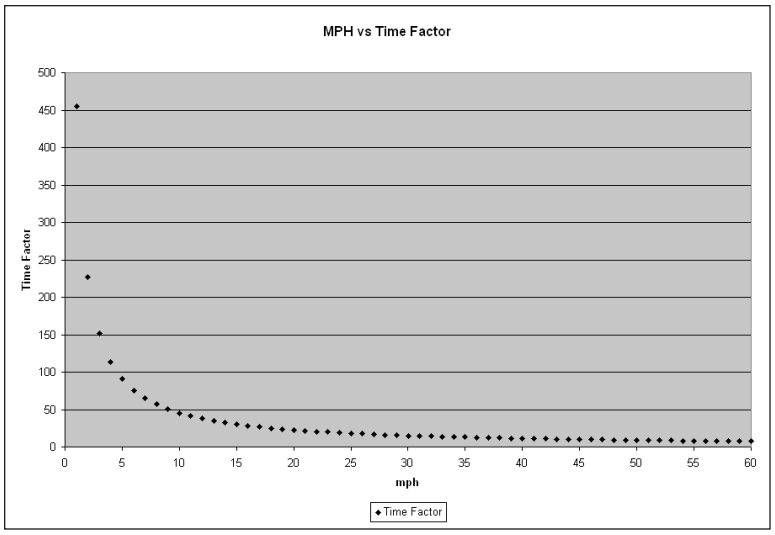

Figure 2. Speed vs. Time Factor.

case, the distance is simulated by a fixed distance. Points would be recorded as if the vehicle was moving at a constant speed, but the vehicle would actually be slowing or sitting still. Thus, the amplitude problem would be acceptable, but the reporting distance would be increased by many additional data points.

The next solution, which handled both the shifting problem and the amplitude problem, was solved by altering the TF variable values directly. This reduced the swing to manageable amplitude. Finally, a slew factor was added to alleviate further the startup swings in the SAG Window. The result is noted in Figure 3 for a SAG case, where the SAG Window is denoted in red.

Integration of SAG Algorithm with WinTK

The WinTK server code was modified to implement the SAG algorithm in two phases. During profile data collection, the speed is continuously monitored. If the speed falls below the SAG start value, a SAG Window is defined and a new time factor value is determined. This new value is then substituted for the time between successive distance signals in the profile computation module. After the profile is computed, the SAG slew value is used if needed. This process continues until the vehicle SAG stop speed is reached, at which time the SAG procedure is no longer applied. Details of the process and code changes are included in the project report. The enabling and controlling of the SAG algorithm in the WinTK Server is controlled by use of the configuration commands applied to the server before data collection. These commands include a switch to turn on and off the SAG algorithm for the profile data, the speed at which the SAG algorithm (SAG Window) begins, the speed at which it ends, the rate of change before applying the slew, and the maximum slew change applied.

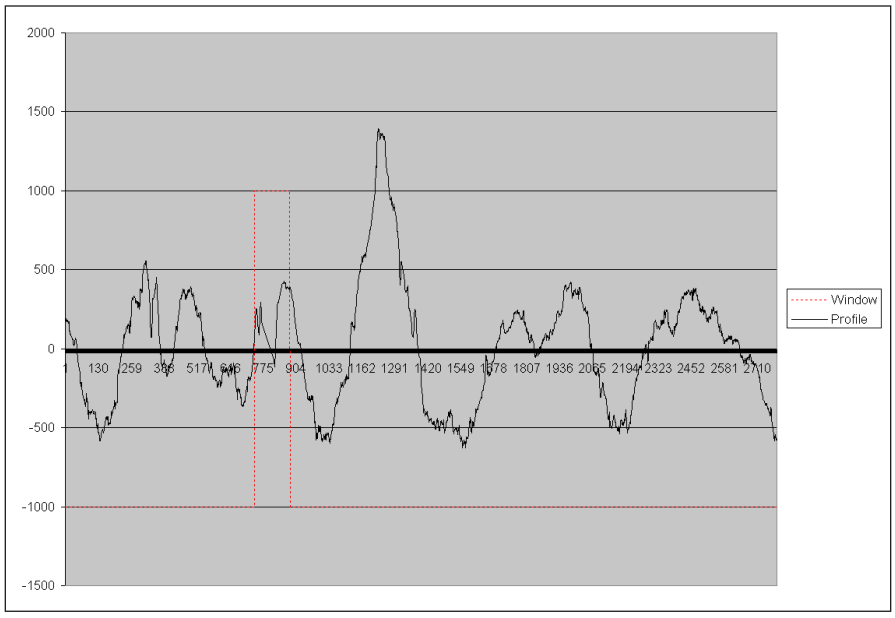

Figure 3. Replacing the Distance Mode with Time Mode.

What We Found…

A method was developed that minimizes the effects of stop-and-go operation for Texas profilers. In tests performed on the Austin test sections, serviceability index (SI) readings were on the average within 0.1 SI. Additional continuous runs were made around TxDOT Design Division Offices on Bull Creek in Austin with numerous SAG occurrences, and no wide profile swings were noted when the SAG procedure was enabled. In development and refinement of the SAG procedure, numerous other runs were made. Program changes were made to WinTK, the UTA-developed server program for profile computation, so that the SAG procedure can be enabled or disabled and various parameters easily set by configuration settings in TxDOT's VAMOS client program.

The Researchers Recommend…

Because of the short duration of this research project, it was not possible to run the procedure over a large number of sections, although it worked well on the sections tested. To determine the usefulness of the proposed method to current network-level data collection, additional usage is needed to make various adjustments. Since the SAG procedure is enabled only during slowdowns and SAG speeds when profile measurements are not used, it is also recommended that TxDOT begin implementing the SAG procedures for PMIS data collections on a limited basis. During its implementation, the SAG configurations can be adjusted as needed.

For More Details...

The research is documented in Report 0-4480-1, *Collecting Stop and Go Inertial Profile Measurements.*

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