Improved position identification method of Train Intelligent Monitoring System to assess track conditions

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1. Introduction

Track inspection is essential to evaluate track condition for maintenance requirements. Several methods to monitor track conditions have been proposed and already employed by some train operators. However, some systems such as track visual inspection are quite laborious, and some require expensive equipments, or need a special train to monitor the track condition. By considering the cost of monitoring, system installation and system operation, a system named Train Intelligent Monitoring System (TIMS)[1)-3)] was proposed. The system consists of accelerometer to record train vibration, GPS receiver to locate the position and a small portable computer for data acquisition. This system utilizes vehicle (train) response to observe track condition, and GPS measurement to obtain the corresponding locations. However, positions obtained from GPS receiver are inaccurate. Thus, the position should be adjusted to obtain precise location estimate before relating them to track condition. This study presents a position identification method for this system.

2. Developing position identification method

1) Field measurement

Measurements were conducted on an ordinary train in Tokyo, Japan. The acceleration response was measured in 3 directions (vertical, lateral and longitudinal direction), but in this study only vertical train acceleration was observed and used to develop position identification method.

2) Assumption of the position identification method

In order to apply the proposed method, the train accelerations of different time measurements measured on the same train and on the same track is assumed to have similar characteristics. A low pass filtering process was applied to acceleration responses in time domain with the cutoff frequency of 0.5 Hz. It was observed that the filtered acceleration responses in spatial domain have the same characteristics. The low-frequency component response at cutoff frequency of 0.5 Hz was chosen to apply position identification method.

3) Position identification method

Because of inconsistency obtained from different measurements, an average position is used instead of the original position. However, the positions from the original data cannot be averaged directly because the corresponding points of each time measurement are unknown. Therefore, a position identification method is developed to find the corresponding point based on the following procedure:

3.1) Define the data frame of interest, for this only peaks whose amplitudes higher than 0.5 of RMS value of the whole section are selected. The segments outside those frames have small responses that are considered negligible. The positions and the sizes of frames ($S_1(x)$, $S_2(x)$, $S_3(x)$ in Figure 1) and other frames (P, Q, R in Figure 1) are equal in all measurements. The selected frames are allowed to shift to adjust the position by selecting one response as a reference.

3.2) Find the shifted distance. By computing correlation function (i.e. $CF_{SY}(\tau_i) = E[S_i(x)Y_i(x+\tau)]$) between the frames of interest of reference response ($S_i(x)$) and the measurement ($Y_i(x)$), the shifting position (τ_i*) that gives the highest correlation value is considered as a gap between the starting point of corresponding spatial frame ($Y_i(x)$) and that of the reference frame ($S_i(x)$).

3.3) For the responses outside the selected frames (i.e. P, Q, R), the response positions are adjusted by shrinking or elongating distance proportional to the shifted positions of the adjacent frames.

3.4) Calculate the average positions from all measurements.

Keywords : TIMS, position identification method, GPS, vehicle response

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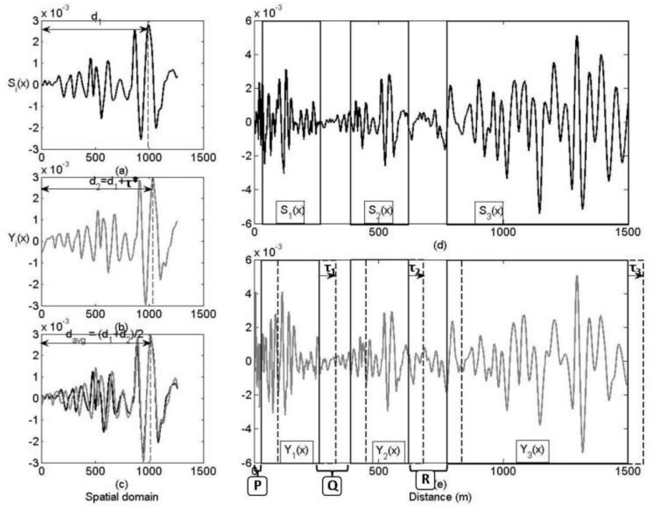

Figure 1 Schematic figures of position identification method: (a) the reference waveform (S(x)), (b) the compared waveform(Y(x)) and (c) the average position of two waveforms in one frame and an example of shifting, shrinking and elongating training data: (d) reference response, (e) compared response

3. Discussion and results

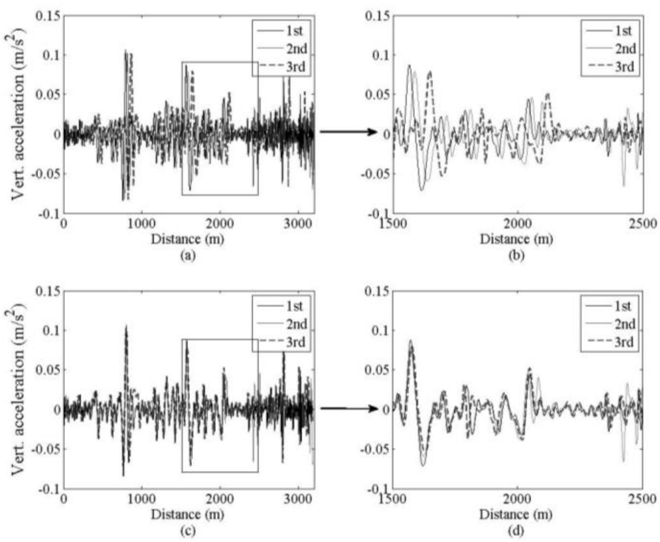

Figure 2 Train acceleration responses of one section: (a) whole section, (b) its zoom in before adjustment and (c) whole section, (d) its zoom in after applying position identification method (Note: the figures are for 1st, 2nd , 3th measurements)

One example section is shown in Figure 2. It is apparent that after applying the position identification method the acceleration responses from different time measurements are relatively close to each other. Error function equation shown in Eq (1) is used to interpret how much the difference between two responses is.

Error function= norm $|\varepsilon_i|$ Eq.(1)

where $\varepsilon_i = |Si(x)-Yi(x)|$

S(x) is the reference response, Y(x) is other response, i is the number of the data point. Norm is defined as the maximum of singular value of ε_i. By computing error function of the responses before and after position adjustment (Table 1), we can qualify the accuracy of position estimation. The error has significantly decreased up to 70% when the filtered frequency cutoff is 0.5 Hz.

Table 1 Error function of the section examples

Section	Error function (m/s^2) Before position adjustment (1)	After position adjustment (2)	%Error decreasing
A	3.2569	0.7700	76.35
B	3.2716	0.4816	85.28
C	2.8027	0.7858	71.96

From these results, we can see that the vehicle responses spatial-wise are comparable. These responses will be later used to assess track conditions.

4. Conclusion

Position identification is an essential part of TIMS. A new technique has been proposed in this study for this position identification. This technique makes use of the correlation function of train acceleration response in low frequency range. Experiment has been conducted and the accuracy of proposed technique has been verified. This technique will be used in the future for assessment of railway by which the position of damage will be identified, while the acceleration response is used for damage qualification.

References

[1] Mizuno Y., Fujino Y., (2008). Development of a mobile sensing units and its prototype implementation. *Tsinghua science and technology*, Vol.13, No. S1, pp223-227

[2] Ishii Y, Fujino Y, Mizuno Y, Kaito K, (2006), The Study of Train Intelligent Monitoring System using acceleration of ordinary trains, *Proc of Asia-Pasific Workshop on Structural Health Monitoring, Yokohama Japan* (CD)

[3] Matsumoto Y., (2008). Locating and Detecting Railway Track Irregularities based on Vibration Responses of a Mobile Sensing System . *Proc. of 63th conference of the Japan Society of Civil Engineers (JSCE)*, Sendai, Japan.