A new Model Based Estimation Algorithm for Train Axle Counting and Detection

B. Allotta, P. D'Adamio, A. Innocenti, E. Meli, L. Pugi

Faculty of Industrial Engineering
University of Engineering
Via Santa Marta n. 3, 50139, Florence
benedetto.allotta@unifi.it pierluca.dadamio@unifi.it
alice.innocenti@unifi.it enrico.meli@unifi.it
luca.pugi@unifi.it

Abstract

This paper presents an innovative model axle train detection algorithm, aimed at performing the train parameters estimation (as its speed V, the crossing times on a fixed measurement point of the track t_i and axle number N_{tot}). The novelty point of the proposed solution is represented by the use of the same approach to determine all the estimated parameters, starting from the knowledge of generic track inputs directly measured on the track (in this work, the vertical forces acting on the sleepers are considered but the algorithm can manage other data input as the rail shear and bending or longitudinal strain and stress on rail). The novelty consists also in the use of accurate multibody models of the vehicle and flexible multibody models of track [1]. The innovative estimation approach to get all the required physical quantities (V, t_i, N_{tot}) is based on cross-correlation techniques. This approach is very low cost and low invasive method because it requires less equipment if compared to the use of track circuits (requiring for example the insulated rail joints installation [2]) and axle counters (requiring for example a double wheel sensor installation [3]): the proposed solution needs instead only of the force sensors, installed on the measurement sleepers. An accurate 3D multibody of railway vehicle and an a detailed flexible 3D multibody track model have been developed by the authors. Such model have been used to tune and test the algorithm as well in every operative conditions, in particular when experimental data are not available. The railway vehicle chosen as benchmark is the Manchester Wagon, implemented in the Adams VI-Rail environment. The physical model of the flexible track has been implemented in the Matlab and Comsol Multiphysics environments. A simulation campaign has been performed to verify the performance of the proposed algorithm and its robustness under different operative conditions. The architecture of the train detection algorithm (Fig.1) is composed of two parts: the physical model and the estimation algorithm. The input of the estimation model can be classified into two types: experimental data or, in absence of them, data provided by a physical model. The purpose of this arrangement consists in the possibility of testing the algorithm performance, even when experimental data are not available, that is fundamental to tune and test the algorithms in all of the operative conditions.

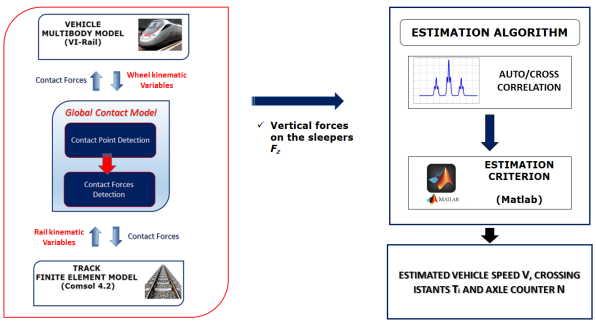

Figure 1: General architecture of the system

The following Figure (Fig. 2) shows a comparison among the speed V percentage errors and their behaviour as a function of vehicle speed V and car body mass M; each graph is referred to a different value of SNR (Signal to Noise Ratio) of the input signal (from 5 to 12 dB): in Fig. 2 the cases with SNR = 5dB and SNR=12 dB are reported for example.

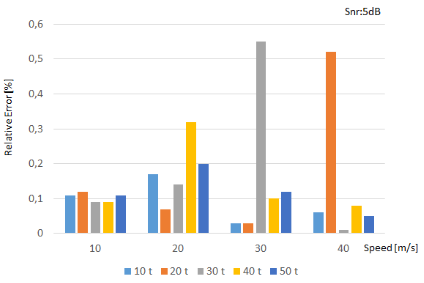

Figure 2: Percentage relative error on the speed V as a function of nominal speed V and car body mass M, for a SNR value of 5 dB.

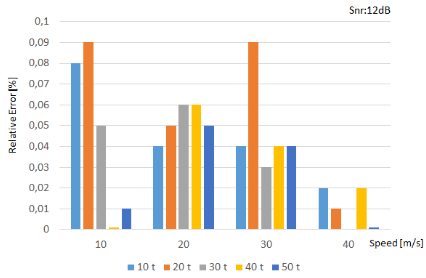

Figure 3: Percentage relative error on the speed V as a function of nominal speed V and car body mass M, for a SNR value of 12 dB.

The performance of the algorithm in estimating the train axles number N_{tot} has been evaluated considering the relative percentage error defined as follows:

$$e_N^{sim} = \frac{\widehat{N}_{tot}^{sim} - N_{tot}}{N_{tot}} \tag{1}$$

where N_{tot} represents the number of crossing train vehicles and $\widehat{N}_{tot}^{sim}$ its estimation value. To test the axle counting performance, the results have been computed performing 100 runs of the algorithm, using the MonteCarlo approach, for each case of vehicle speed V and car body mass M (the maximum error is considered). For example, the global results in estimating the axle number are reported in Tab. 1 with different values of SNR (from 8dB to 12 dB).

Table 1: Error on estimating axle counter N_{tot} with variable speed V, car body mass M and SNR of the input signal

Speed $[m/s]$	Mass [t]	S/N=8db Err.[%]	S/N=9db Err.[%]	S/N=10db Err.[%]	S/N=11db Err.[%]	S/N=12db [%]
10	$M = 10t$	12	4	2	0	0
	$M = 20t$	17	3	1	0	0
	$M = 30t$	18	5	1	1	0
	$M = 40t$	16	9	2	1	0
	$M = 50t$	15	10	3	1	1
20	$M = 10t$	3	0	0	0	0
	$M = 20t$	5	0	0	0	0
	$M = 30t$	6	3	1	0	0
	$M = 40t$	1	3	1	0	0
	$M = 50t$	8	2	1	0	0
30	$M = 10t$	1	0	0	0	0
	$M = 20t$	1	0	0	0	0
	$M = 30t$	3	2	0	0	0
	$M = 40t$	2	0	0	0	0
	$M = 50t$	6	2	2	0	0
40	$M = 10t$	4	4	1	0	0
	$M = 20t$	12	3	3	2	1
	$M = 30t$	10	5	3	0	0
	$M = 40t$	4	3	1	0	0
	$M = 50t$	3	3	0	0	0

Results show the good performance of the estimation algorithm in estimating V, t_i and N_{tot} even in the worst case of low SNR and highlight the accuracy and robustness of the proposed approach.

References

[2] J. Palmer. The need for train detection. In Railway Signalling and Control Systems, pp. 47–53, York, England, 2006.

[3] A. Zamani, A. Mirabaldi. Optimization of Sensor Orientation in Railway Wheel Detector, Using Kriging Method. Journal of Electromagnetic Analysis and Applications, pp. 529–536, 2011.

[1] E. Meli, L. Pugi. Preliminary development, simulation and validation of a weigh in motion system for railway vehicles. Meccanica, Vol. 48, No. 10, pp. 2541–2565, 2013.