Development of a real-time on-board system for the measurement of track irregularities

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EXTENDED ABSTRACT

1 Introduction

Railway tracks must guarantee the correct guidance of the vehicle without compromising stability, safety, or passengers' comfort. Unfortunately, these three requirements are usually in conflict since actions taken in one of them disturb the others [1]. Deviations from the track's ideal geometry produce undesired responses, leading to poor ride quality, or even jeopardizing the vehicle's safety. These deviations are the so-called track irregularities, which are described in the railway industry through the following four variables [2]: 1) track gauge variation, 2) lateral alignment, 3) cross-level and 4) vertical profile. The first two define lateral deviations while the last two define vertical deviations of the track. To ensure the optimum safety and control of the vehicle, the European standard EN133848 [3] stablishes the maximum level of deviation on each irregularity according to their wavelengths.

Railway companies and track operators demonstrate a huge interest in the correct and precise measurement of these irregularities but are faced with high cost and complexity systems. Nowadays, there are two different approaches for the measurement of track irregularities that can be found on the literature. On the one hand, high precision manual methods include an instrumented trolley pushed manually along the track, usually involving the use of a total station, resulting in high precision but inefficient measurements [3, 4]. On the other hand, automated methods involve laboratory vehicles fully instrumented with high-precision sensors and on-board computers, allowing faster measurement of track irregularities [5, 6]. However, its high cost may make them prohibitive for most companies.

The current challenge for railway engineers lies in the development of a fast, precise, reliable and cost affordable system which can be installed in any commercial line vehicle, putting aside sophisticated and highly cost laboratory vehicles. During the last decade, the Department of Mechanical and Manufacturing Engineering of the University of Seville has been working on the development of a new measuring system that meets these requirements. This paper deals with the development of a new measuring system based on the utilization of computer vision, inertial measurement, and a simple kinematic model of the vehicle that allows the real-time measurement of the four track irregularities. The final goal is the development of a universal measuring system that can be adapted to any railway vehicle and can be operated by any company at a reasonable cost.

2 Applied methods

The method for the automated measurement of track irregularities presented in this work has been experimentally validated using a scaled track and an instrumented vehicle. Despite the scale reduction, the method can be extended to a full scaled system with equivalent performance and results. Figure 1(a) shows the scaled track. This is a unique facility where track irregularities can be manually introduced using a series of mechanical slabs distributed along its 90 meters of length. The geometry of the track is measured in advance using another very accurate method different to the one presented in this paper. Figure 1(b) shows the instrumented scaled vehicle. It represents a full vehicle including two bogies that support the car body. The vehicle is instrumented with two high-speed cameras and projection lases, an IMU and an odometry system, all connected to a Real-Time (RT) computer able to acquire the sensor signals synchronously and calculate track irregularities at 250 Hz.

In addition, computer vision algorithms have been previously tested indoors, using a four degree-of-freedom robot capable of reproducing railway irregularities as seen by the vehicle moving at constant speed through four linear actuators. Figure 1(c) shows the complete system, including two high-speed cameras and projection lases and four laser distance sensors, used to compare and validate the computer vision results.

(a) (b) (c)

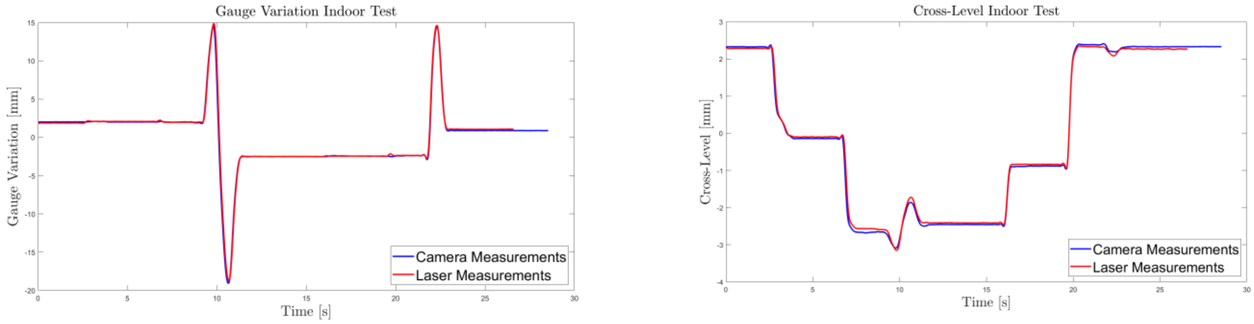
Figure 1. (a) Scaled railway track. (b) Instrumented vehicle. (c) Indoor robot.

3 Results

Indoor tests of computer vision algorithms have yielded promising results, as shown in Figure 2, where real-time track gauge variation (a) and cross-level (b) measurements are represented. Large values of these irregularities were imposed on the robot in order to take into account the possibility of the cameras not being strictly on top of the rails.

Outdoor tests have revealed additional challenges derived from external conditions, such as noisier camera signals due to sunlight reflections, which have led to the need of developing additional filtering algorithms on top of the ones included in the high-speed cameras. Furthermore, the rest of the sensors were included to estimate the vehicle's trajectory along the track with a Kalman Filter.

The main contribution of this work lies in the capability of the developed system to measure track irregularities in real-time. In a preliminary work [7], this research team presented similar results but, it that case they were obtained off-line. This new system also counts with a improved algorithm for the obtention of the rail-head positions and complementary digital filter that allows the reduction of the influence of external reflections.



(a) (b)

Figure 2. Real-time measurement of (a) gauge variation and (b) cross-level.

4 Conclusions

This work presents an innovative track irregularity measurement system that allows the on-line inspection of an arbitrary track. The system proposed is intended to be universal for any line vehicle, since it is based on a kinematic model that does not accounts for the vehicle dynamics. The obtained results in the laboratory and the results from the outdoor test on the scaled track reveal the huge potential of the system, been able to capture the four irregularities of the track in real time. As future work, this research team is working on an extension of the system that also allows the measurement of the ondulatory wear of the rail, also known as corrugation, and the inspection of the rail head's wear.

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