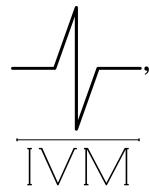




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## UIC Digital Awards 2017

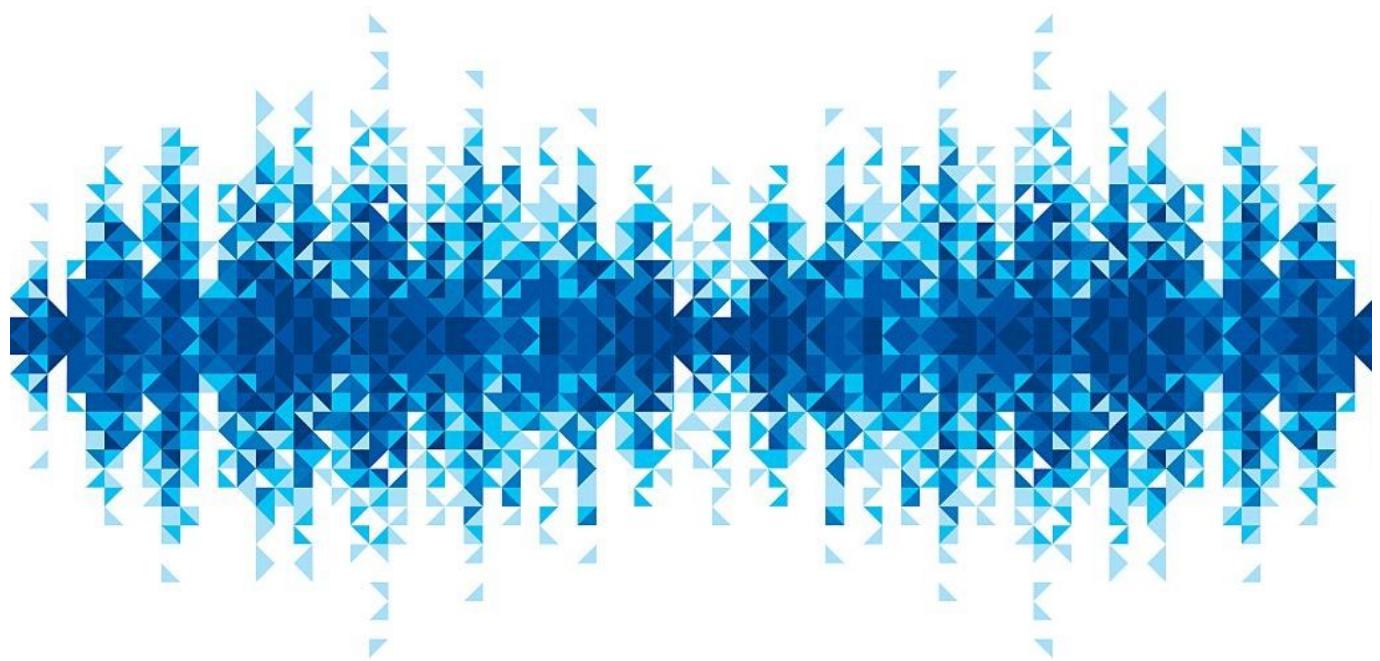


IVM S.r.l.

[www.ivmtech.it](http://www.ivmtech.it) - Italy

### DATA ANALYSIS FOR SAFETY

#### Accelerations revealing the Wheel-Rail interaction



## Abstract

*IVM is an Italian start-up focused on diagnostic systems for railway domain. We decided to compete to the “UIC Digital Awards 2017” with our sophisticated sensor technology and data processing chain that diagnose degradations and faults in railways.*

*We treat and process thousands of acceleration samples per second from onboard systems, technically solving the most demanding problems of the “data era” including data transfer, data fusion and advanced techniques for Big Data processing.*

*This document presents the Company, its vision and product portfolio, then a detailed description of the Big Data and Sensors Infrastructure challenges we are solving. The document concludes with the global challenge, the impact that our solution has on the mobility and sustainability of the railways.*

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## 1. Company Introduction

IVM S.r.l. is an Italian company founded in 2014 and recognized Innovative Startup under Italian regulation<sup>1</sup>.

IVM embraces the skills and experiences of its members and over twenty years working experiences of the entire team. Such experiences are mostly gained while conducting numerous research and product exploitation activities performed in close collaboration with Universities, Research organizations and large companies.

The most significant part of the experiences of IVM, can be synthesized in the ability to realize monitoring and diagnostic systems based on the innovative use of integrated sets of sensors. The holistic view of IVM's systems provides the possibility to extract much larger informative contents with respect to the sum of the information obtainable from the individual sensors.

Thanks to the résumés of its members and staff, and thanks to the many experiences in several research projects, *IVM is offering products that are based on the innovative use of sensor and the application of advanced technologies for data processing*.



### 1.1 Research and Innovation

IVM is devoted to creating innovative diagnostic systems for railway and train maintenance. Our vision is that a better understanding of the wheel-rail interaction can lead to a safer, more sustainable and comfortable railway domain.

In order to understand the wheel-rail interaction, we had developed specific technologies to measure what happens when a train passes over the rail. Our research oriented approach and the presence of

<sup>1</sup> <http://startup.registroimprese.it/isin/dettaglioStartup??&id=KXU3bCJQBfS92AJOXqJVKg%2BWN%2B7pDSoya0lVA7how%3D%3D>



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four Ph.D in the team, guides us in always improving the technology and the products to extract always more knowledge from the data.

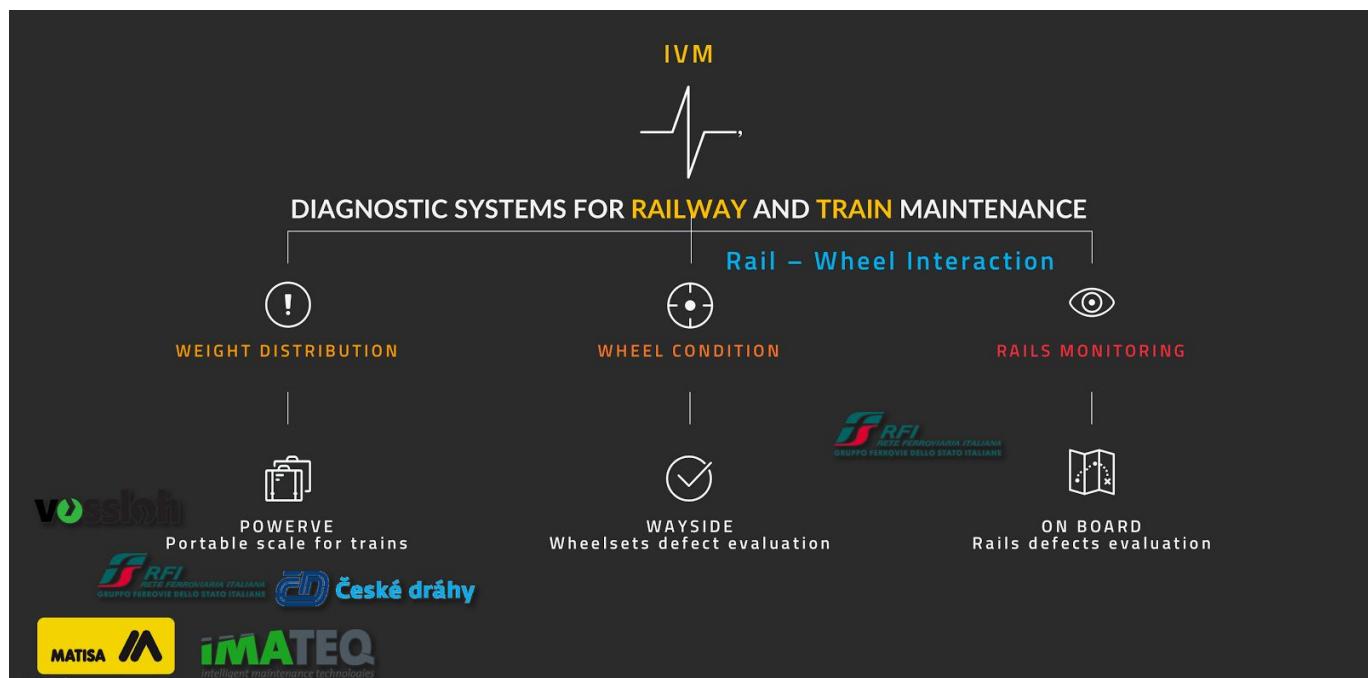
The wheel-rail interaction problem requires to fully understand the behaviour of the train when it passes at a wide range of speeds. We focus on this interaction from two complementary point of views. The point of view of the train, thus measuring from an on board system, and from the track point of view, thus measuring from a wayside system.

These systems share the same acquisition technology, the hardware and several data analysis algorithms. Each of the measuring systems collect thousands of accelerations per second and are able to fully synchronize the acquisition from their sensors in order to guarantee best quality data. Thanks to the synchronization, our data fusion and data processing chain is able to treat the multiple acquisition point of a measuring system as a single acquisition point giving an holistic view on the phenomenon.

## 1.2 Brief outline of our products

The two measuring products are able to capture the dynamics of the wheel-rail interaction. On the other hand, another key factor is the correct understanding of the weight distribution in order to measure how much each wheel statically loads on the track. For this reason IVM has also focused his innovation activities into developing a solution for easily and correctly weighing a train.

Up to now, IVM products portfolio is composed of three main products and several services connected to them: (1) POWERVE - a portable scale for trains, (2) SWAN-T - a wayside Wheel Condition Monitoring and (3) IQM-WTI an innovative system for assessing the quality of the wheel-track interaction.



### 1.3.1 POWERVE

<http://ivmtech.it/en/prodotti/powerve/>

The first and only fully portable system to weigh trains. We, at IVM, have engineered an innovative measuring instrument which measures the static



weight force distribution loaded on track, by each rolling stock wheel.

The particular design allows the rolling stock to stay still without the application of external constraint or forces. Therefore, the weight is not affected by tensions due to the braking forces.

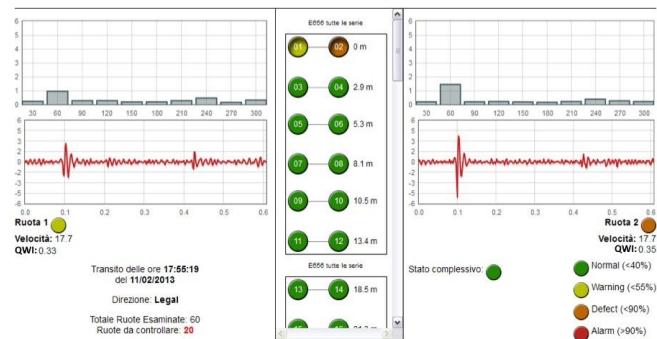
### 1.3.2 SWAN-T

<http://ivmtech.it/en/prodotti/swan-t/>



SWAN-T provides valuable information on the quality of the rolling surface of each wheel, in order to perform an “on condition” maintenance of the rolling stock, reducing maintenance costs and increasing operating safety.

SWAN-T provides a QWI for each wheel of a train, classifying them into three synthetic levels, L0-L1-L2, represented in green-yellow-red colors.



### 1.3.2 IQM-WTI

<http://ivmtech.it/en/prodotti/iqm-wti/>



IQM-W/TI is a system designed to monitor the wheel/rail interaction, by measuring the axle box accelerations during rolling stock running. It consists of several sensors, installed in different points, acquired with absolute synchrony and georeferenced by a GPS. The absolute synchronicity of the acquired accelerometric data and the sophisticated data processing, allows to obtain diagnostic informations of the wheelset/track interaction, of the bogie/rail interaction and of the wagon/rail interaction.

## 2. The wheel-rail interaction (WRI), a Big Data and Sensor Fusion problem

The challenge of understanding the interaction between wheel and rail has always been of great interest in the railway domain. The wheel-rail interaction is a complex phenomenon which is fundamental to:

- fully understand how a train behaves ,
- measure the stress it is exposed during the running.

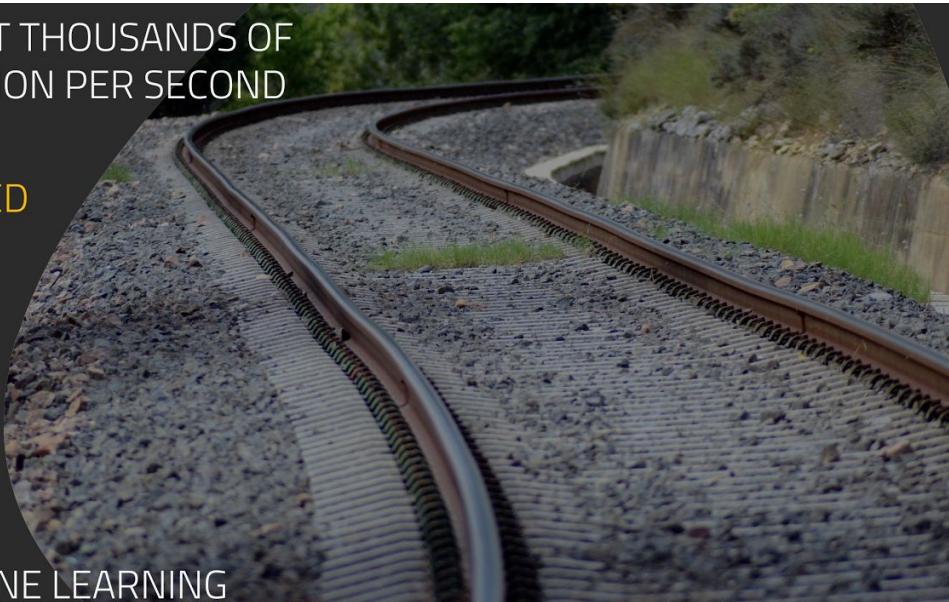
The main focus of WRI is on safety improvement, maintenance costs reduction, downtime reduction, and energy and environmental management.

Generally, the WRI is studied in an indirect way in the sense that the wheel and the rail are deeply studied and measured by means of dedicated and separated technologies: (1) wheel profile measurement systems and (2) diagnostic trains equipped with sophisticated geometry measurement systems. On the other hand, our approach and vision to this problem is based on the actual measurement of the interaction which is expressed in the form of accelerations insisting on the axle box. This approach, as well as the more common and widely used solutions, collect a huge amount of data per transit; but this doesn't imply that this is a Big Data problem.

## WE COLLECT THOUSANDS OF ACCELERATION PER SECOND

FOCUS ON THE  
ON BOARD SYSTEM  
**UNTETHERED**

BIG DATA  
AND MACHINE LEARNING



*What it really makes our approach a Big Data and Sensor Fusion challenge is that we are developing a new technology that can be installed on any kind of train (public transport or freight) and thus allowing a continuous monitoring of all the infrastructure.*

Our “untethered” technology has a very small installation footprint and does not require connecting to on board systems of the train. Thanks to a dedicated hardware, a sophisticated positioning system and a fault-tolerant communication mechanism, our solution is able to collect thousand of data per transit on a wide number of train and collect high quality raw data.

Without an high quality of the input data in terms of synchronization and positioning it wouldn't be possible to perform analysis in time and space and it will be impossible to perform advanced statistical and trend analysis.

### 2.1 Our Roadmap

IVM focused on these system since early stage, starting from the long-time experience and technical background of the team. Our first milestone was developing a dedicated acquisition system in order to collect high quality data in terms of synchronization and positioning. Then we were able to understand that the knowledge we can extract from the accelerations is huge and the defects identification is just a small portion of it.

We have deeply tested and proved our approach thanks to the installation of a working prototype on a testing train of the Italian network manager RFI. We collected an average of two transit per week and collected data for almost 75.000 Km in a year (09/2015-09/2016).

Our current focus is on the development of a system to continuously extract features from the data present aggregated and trend view based on network map in false colors.

We are supporting our project with a **2 millions grant in 3 years** from the Italian Government in collaboration with Universities (**CeRICT** - <http://www.cerict.it/en/>) and another Italian Company (**DMA** - <http://www.dmatorino.it/>) which is focused on onboard systems for track geometry measurements.

## THE PROBLEMS WE ARE SOLVING



### DATA COLLECTION

GET DATA YOU  
CAN TRUST

Advanced synchronous network of  
accelerometers



### DATA TRANSFER

EFFICIENCY AND  
SECURITY

Move the data from on board to the  
processing Cloud



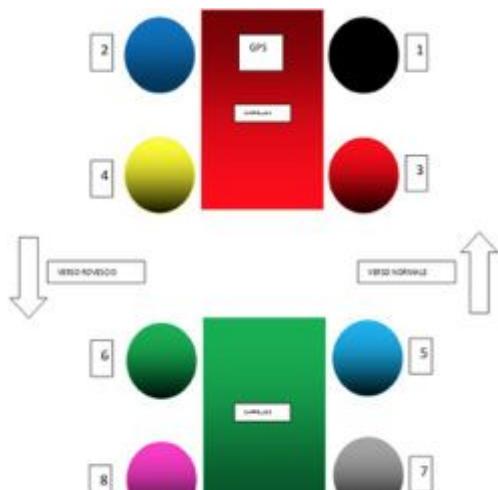
### DATA COMPARISON

IN SPACE AND  
TIME

Compare the data from different  
Trains and several Transits

## 2.2 The measuring system

The measuring system requires the instrumentation of one or two sets of bogies with accelerometers installed in the axle boxes. The **accelerometers** share a communication and synchronization bus and are connected to a **processing unit**. The processing unit collects all the data, adds **georeference** and location information and **transfers** the data to the cloud with a fault-tolerant proprietary communication protocol which guarantees **high throughput and reliability** over mobile connection.



Two instrumented bogies, a total of eight 3-axis accelerometers and one GPS.

Detail of accelerometers on the axle box

## 2.3 What knowledge can we extract?



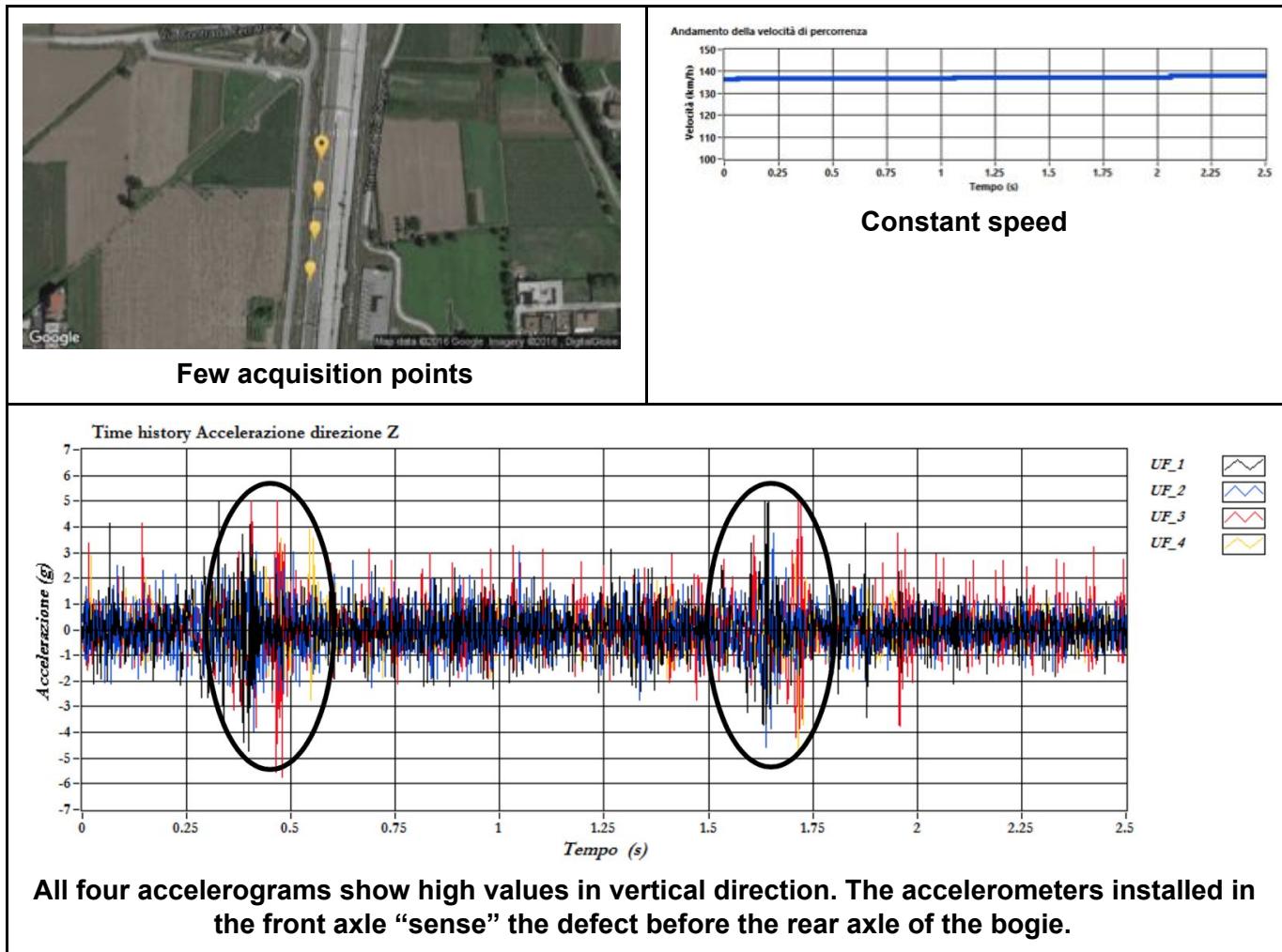
Our WTI monitoring system can be used to study and extract a lot of knowledge about the track and the train running behaviour. These information are extracted through a sophisticated fusion of temporal analysis and analysis in frequency.

In this section, we report the main information we can extract by analyzing a single or multiple transits.

### 2.3.1 Specific events correlated to the track

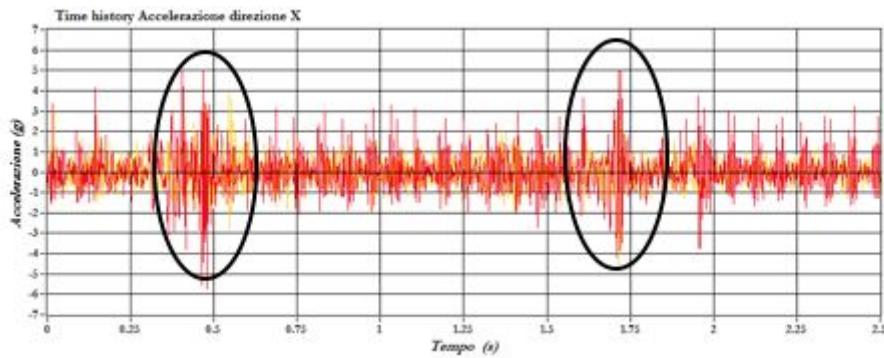
The system can identify peaks in the data that are directly correlated to the presence of anomalies in the rails.

Consider a small portion of data collected at constant speed. We can extract just few seconds of accelerations samples per each sensor in a bogie, and we can identify the presence of impulses (peaks) caused by defect on the track.

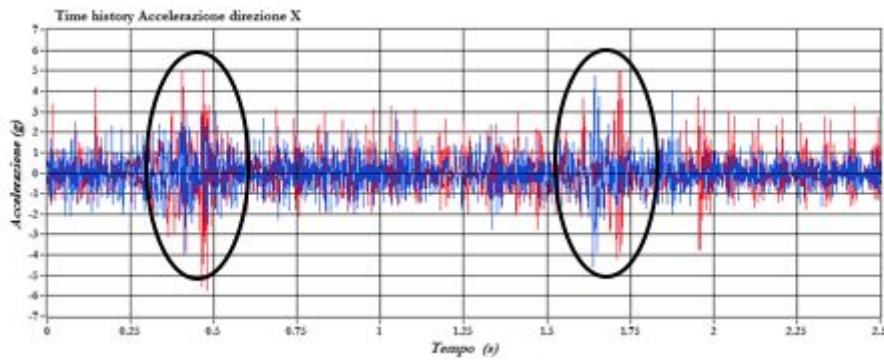


### 2.3.2 Temporal correlation between sensors of the same bogie

The presence of anomalies, defects, switches and joints can be identified by the sensors in a set of wheels. To better correlate and certainly associate this peaks to the rails, we correlate and look for their presence in the data of the front axle and in the rear axle of the bogie. We can precisely identify the correlation by analyzing the temporal distance of the data which is dependant on the distance between the axles. We can also perform this correlation analysis between the data of two instrumented bogies.



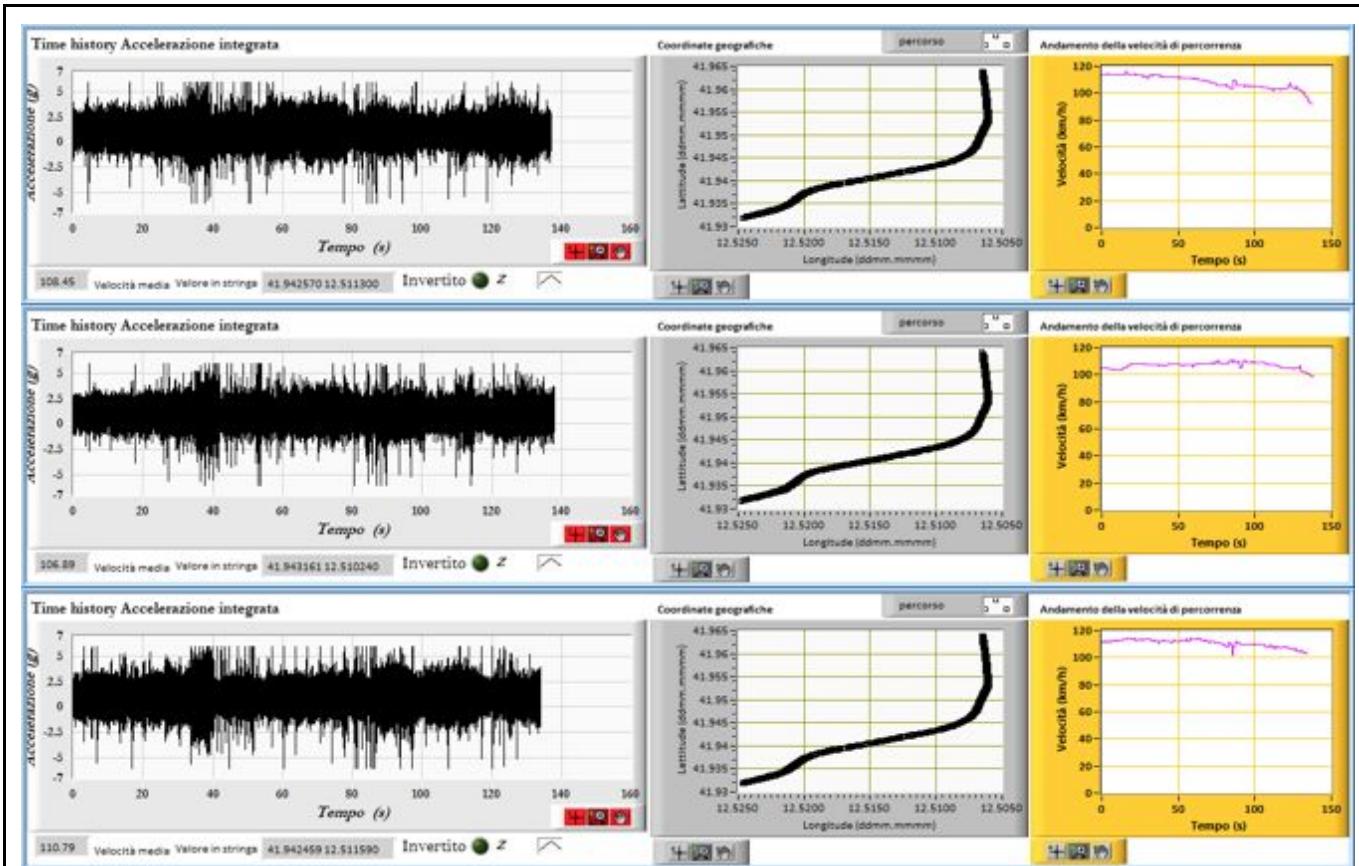
The peaks on the wheels of the same axle are present in the same instant of time



The peaks on the wheels of two different axles are present in two instants of time. This time are out of phase of a temporal amount directly correlated to the distance of the axles and the speed of the train.

### 2.3.3 Are the results Repeatable?

The main requirement for performing a good data analysis and transform the data in quantitative measures is to have a repeatable acquisition of the data. We have performed an in depth analysis to understand the condition for repeatability and we identified that different transits of a train in different moments of time are highly repeatable if performed with a similar speed profile.

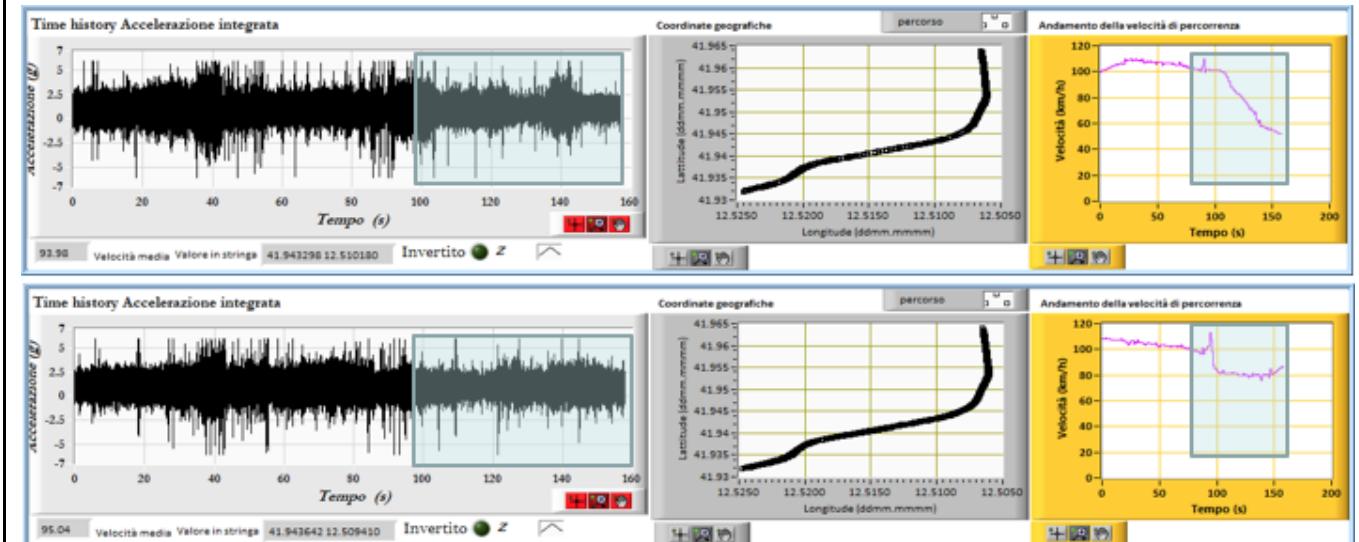


Accelerogram

Location Map

Speed

Three different passes, with an average speed of 110 Km/h and a similar speed profile. The accelerograms are highly repeatable.



Accelerogram

Location Map

Speed

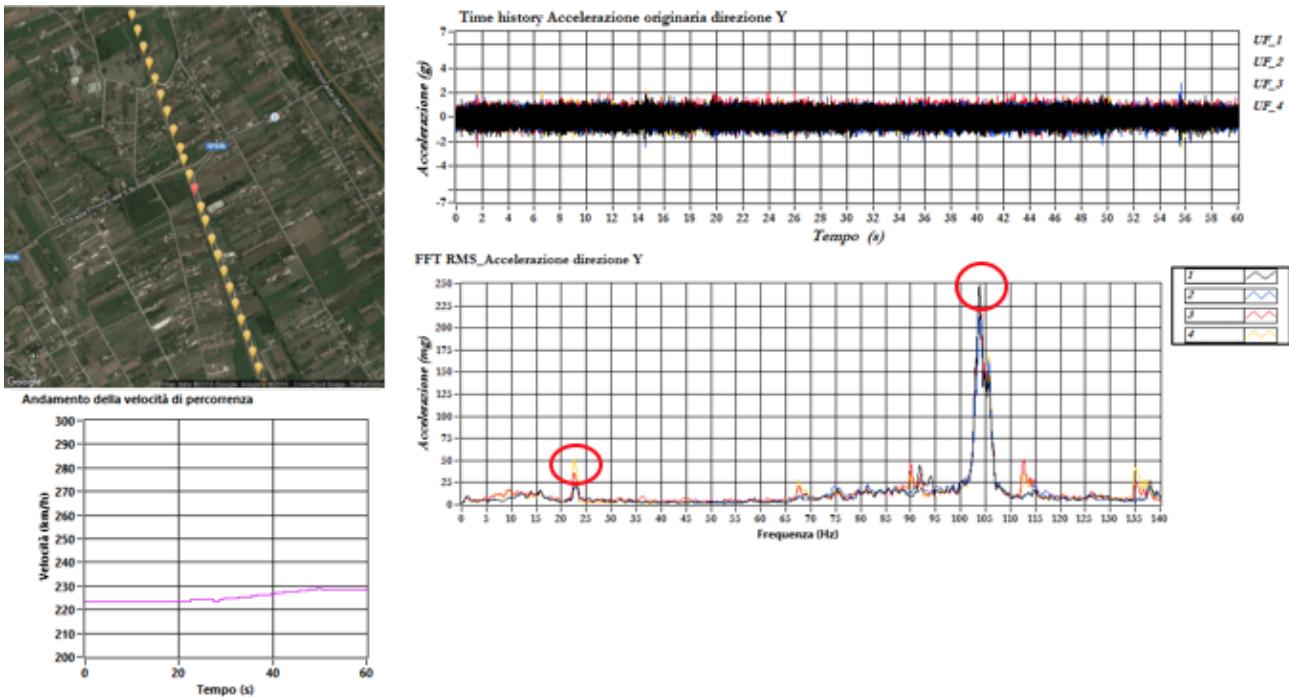
Two passes with different speed profile. The data show a different accelerogram.

### 2.3.4 Long period phenomena

Consider the data collected at quasi constant speed on an almost straight track without significant track anomalies.

The transversal accelerations show a signal of uniform amplitude for all four sensors of the bogie.

There is no evidence of peaks but stationary phenomenon are present and located at specific frequencies. What information can we extract?



As the frequencies analysis show there are two notable peaks. Considering the average speed of 225 Km/h and transforming the frequency in wavelength we can extract information about the spatial distance of these repeatable events.

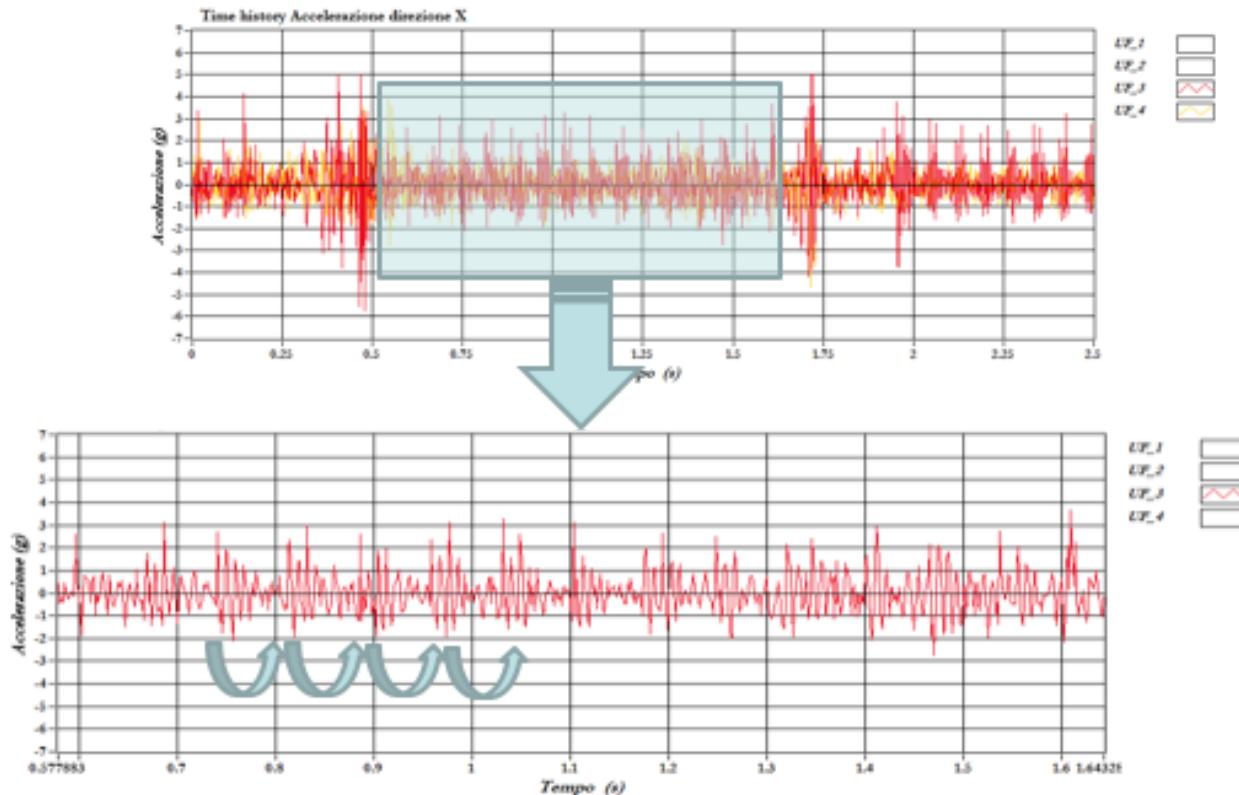
The highest of the two can be correlated to the distance of the **railway sleepers**, more or less 60 cm. The other peak can be correlated to the **linear development of the wheel**, more or less 2.8 meters.

### 2.3.5 What effect does the train induce itself?

If we consider the accelerograms from a section without peaks correlated to track irregularities, we can extract the influence that the train itself is generating.

If we zoom in the signal we can identify phenomenon which happens repeatedly (every 0.075 seconds - at a speed of 135 Km/h this corresponds to every 2.8 meters, that is the linear development of a wheel).

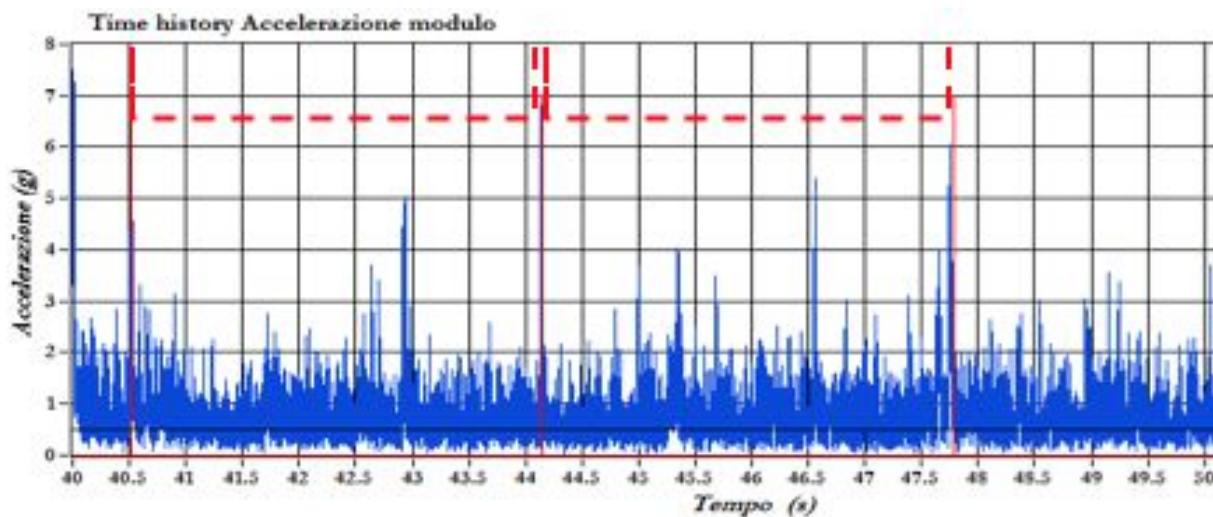
A deeper analysis show that this cyclic phenomenon is present on each sensor but with a different fingerprint. The general idea, is that this behaviour can be directly related to the wheel condition and its specific profile or defects.



### 2.3.6 Can we identify rail weld points?

We performed a specific data analysis to identify the presence of rail weld points. We have seen that a fingerprint of the effects of the weld point on the wheels can be extracted through a modulo analysis.

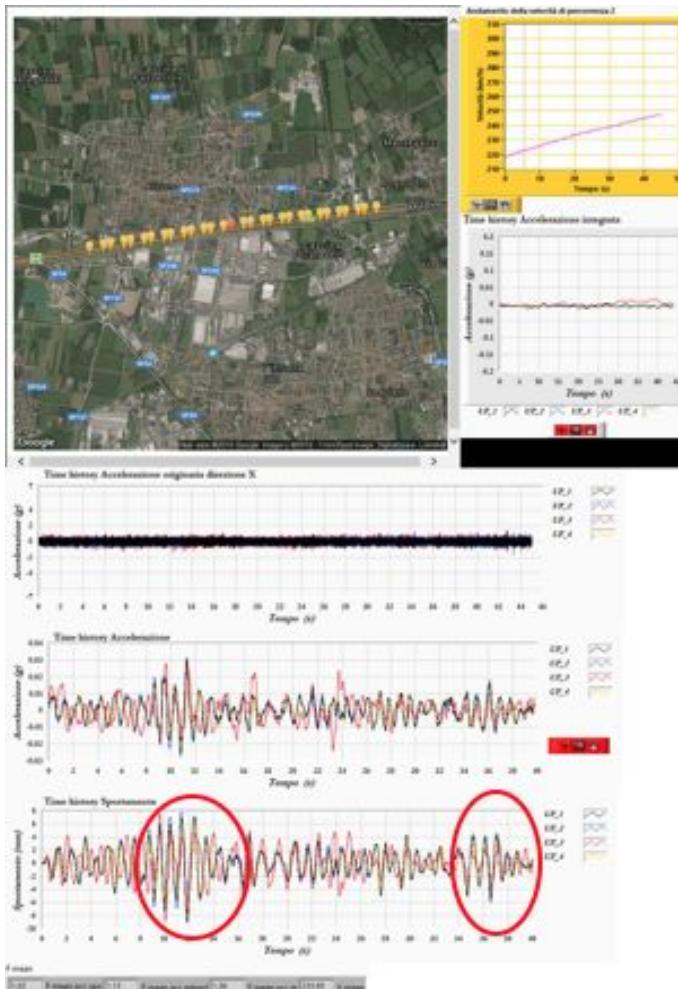
In the image that follows the red peaks are spatially distant 108 meters which is compatible with the distance of weld points. This kind of peaks can be identified with repeatability for all the transits at same speed.



### 2.3.6 What about the train hunting?

We are also able to identify the train hunting by a specific data processing chain. We extract a portion of accelerations from a straight track at constant speed. We derive from the original acceleration the low

frequency contribution. What we can derive from these data is a movement with evidence of oscillating damped contributions. This can be correlated to the train hunting.



### 3. The impact on mobility and railway

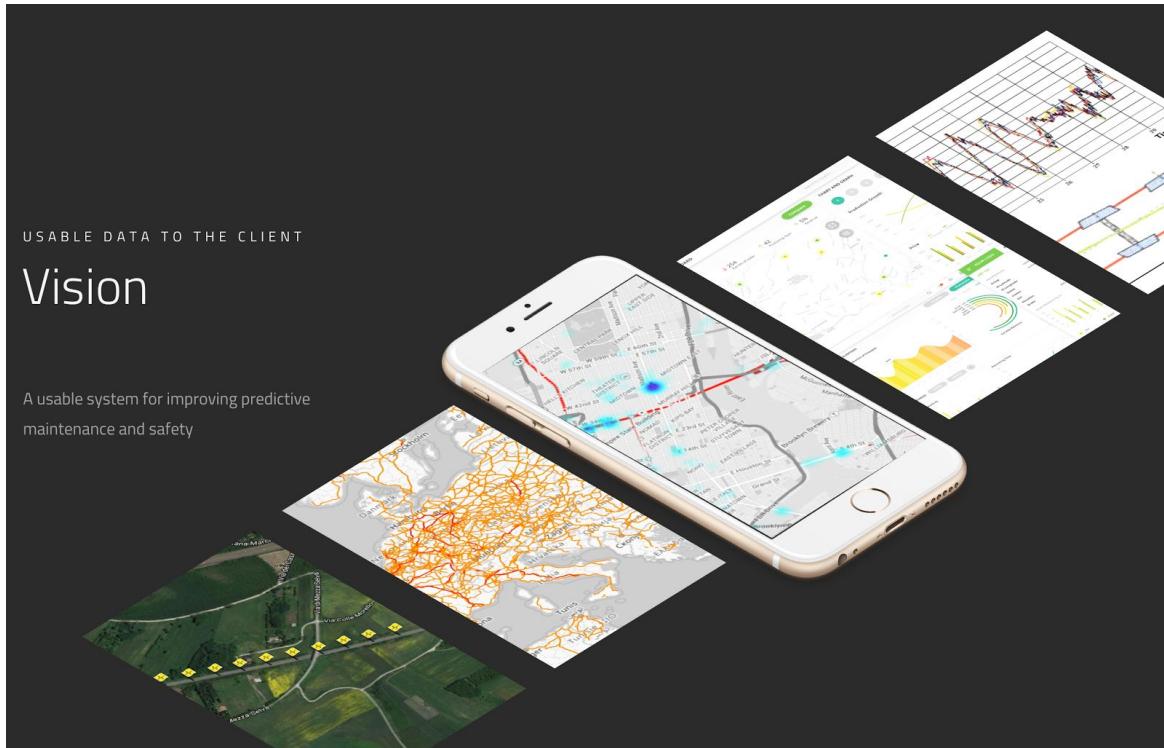
As we have shown we can identify and correlate a huge amount of information extracting knowledge that is of great interest for the railway stakeholders. But what are the impacts that such system can have in terms of mobility and railway global challenges?

Our solution and approach to wheel-rail interaction sector is based on a advanced hardware architecture and a scalable communication and processing system. This allow us to fully exploit the advantages of the Cloud. The capability of designing, implementing and managing Cloud infrastructures allow us to offer trend analysis, track features lookups in space and time and aggregated data that Railway infrastructure managers strive to get.

Our vision, that is becoming a market product thanks to investments, European/Italian Government funding and collaboration with relevant stakeholders, is to offer a system that can be installed on the majority of the trains running every day on the line.

This will allow to extract a huge amount of information about the track and the trains themselves which we have already proven to be of great interest for network managers.

The product we are building will fully exploit the Big Data processing and Cloud scalability in order to offer to the railway managers a usable system for improving predictive maintenance and positively impact the overall safety.



One of the key advantages of our approach where every train can be an active sensor, is that this will offer a frequent, almost continuous in time, monitoring of the infrastructure and the fleet. It will offer the “golden data” for improving the predictability and proactively plan the maintenance. Moreover, thanks to high accuracy of positioning and the ability to verify the presence of anomalies with multiple passes, the infrastructure manager will be able to reduce downtimes and close shorter sections of the railways.

