# Track Geometry Measuring System

# RailwayTrack

The regular railway inspection is essential for railway safety and railway maintenance optimization. RailwayTrack is intended for the integrated track control of track geometric quality parameters:

- *track geometry* – track gauge, longitudinal level, alignment, cross level (cant/superelevation), twist, curve parameters, etc.;
- *rail surface defects* – corrugation, squat, wheel slipping points, etc.;
- *train dynamics and driving comfort* – acceleration and angular rate of car body and truck axle-boxes;

The system combines the measurement of track geometry parameters with precise localization of measuring point through geographic coordinates (latitude and longitude).

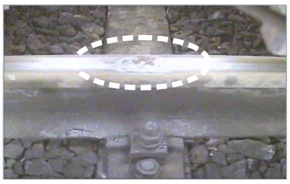
With modular implementation, the system can be easily mounted on the bogie of any moving railway unit and used independently as well as integrated in the software and hardware of track inspection vehicles.

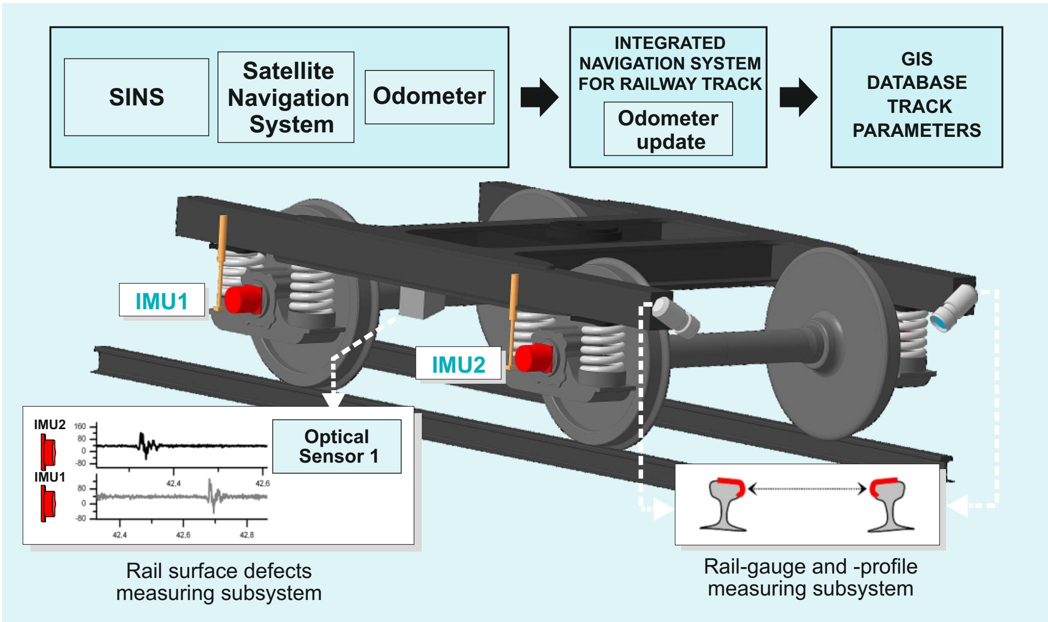
High operating speed allows the system use for inspection of the high-speed railways current state and estimation of the driving comfort.

Highly accurate measurement of railroad track geometry allows the system use for control of the track geometry during acceptance tests after railway maintenance works.

## Functional subsystems

IMU on axle-box






RailwayTrack system comprises both specially developed and off-the-shelf devices.

### Inertial Measurement Unit - IMU

IMUs measure angular rates and linear accelerations of axle box. IMUs comprise Micro-Electro-Mechanical-System (MEMS) gyros and accelerometers measuring these parameters along three orthogonal axes. IMU also comprises an ADC and data processor.

MEMS sensors offer high sensitivity, vibration and shock resistance along with compact size and low weight, which allows IMU mounting directly on journal box lids.

### Strapdown Inertial Navigation System - SINS

SINS integrated with a receiver of satellite navigation system is based on MEMS accelerometers and fiber-optic gyros. It is installed on the truck frame or in the car body.

SINS outputs the following parameters

- position,
- linear speed,
- attitude (true heading, track angle, roll, and pitch),
- projections of acceleration and angular rate on the SINS frame.

## Optical attitude determination system

The optical system consists of three emitting sources and three receivers mounted on the car bottom and truck frame. Therefore, a contactless system is formed to measure mutual orientation of the truck where IMUs are installed and the car body where satellite receiver is installed.

## Video system

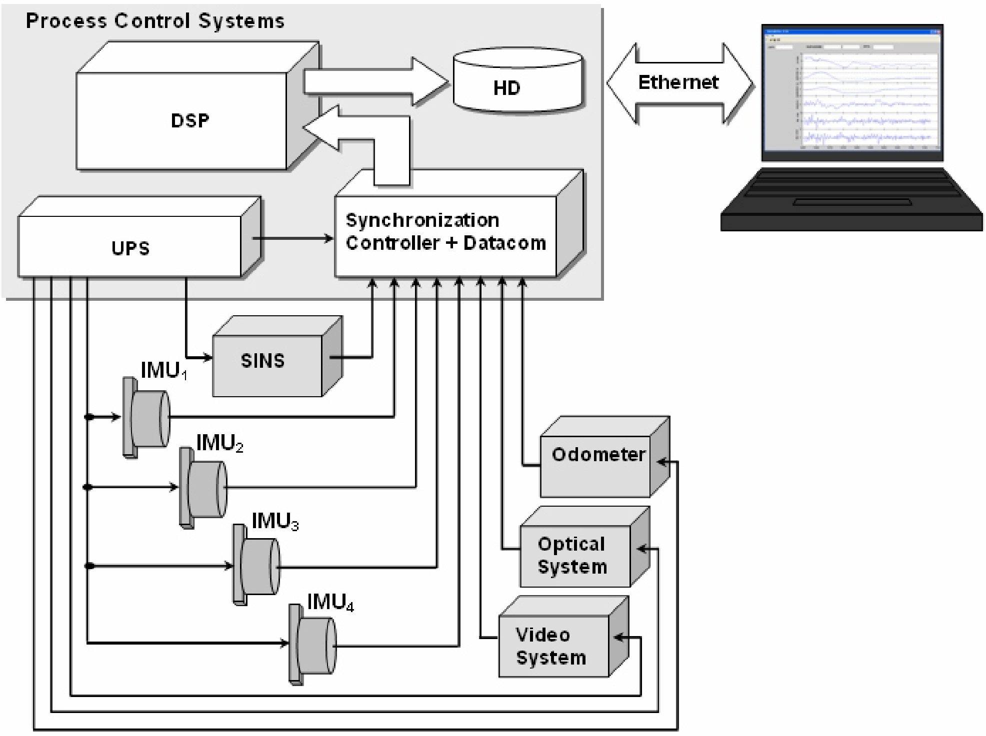
The video system for monitoring the track defects is based on digital video cameras and is mounted on the truck frame between the wheel pairs. Camera records are filed only for path segments and intervals when suspected defected spots, registered by IMUs of the first wheel pair (in the train direction), are passed and registered by IMUs of the next wheel pair. This algorithm, as opposed to continuous video recording, saves memory resources and facilitates postprocessing.

## Odometer

Odometer is a main device used to measure the distance traveled by the measuring devices. It is mounted on one wheel pair.

## Process control system

PCS comprises uninterruptible power supply (UPS), signal synchronization and transmission board, digital signal processor (DSP), and hard disk (HD) packaged in a metal casing, and has USB, Ethernet and other interfaces.




# Interaction of subsystems

The wheel pairs are the principal and the most loaded parts of the truck. Periodically occurring track defects affect the dynamics of the car spring-borne and non-spring-borne loads through the wheels during their interaction with the rails. The car dynamic reactions include its oscillations and vibrations, which can be described in terms of changing acceleration and rate vectors.

The rail-produced actions experienced by the wheel such as impacts and shocks are registered by the inertial modules (IMU1…4).

Before using SINS and IMU1…4 within the integrated system, they are calibrated on a special measuring test bench [1, 2]. Each module is equipped with a temperature sensor to provide self-calibration within the temperature range from – 40 to + 60˚C.

The proximity of module to the point of wheel-rail contact allows the measurement of short irregularities such as short rail profile defects (up to 600 mm long) and part-through flaws (up to 200 mm long).

Short irregularities are determined using the correlation analysis. IMU signals are processed in separate units for the left and right rails. Suspected irregularities are compared with the video records.

Short irregularities are superimposed on long irregularities characterizing the horizontal and vertical space curves. Long irregularities are caused by roadbed residual deformations resulting from soil compaction due to multiple passages of heavy trains. As regards the action produced on the moving car, long irregularities produce no shocks. The car reaction to these actions is described by low-frequency oscillations.

Gradient and superelevation are calculated by SINS and optical system data. SINS outputs the attitude parameters (heading, roll, and pitch) with respect to geographical frame, and optical system outputs parameters of car body and truck mutual orientation. Difference of these readings provides the true horizontal and vertical space curves.

The navigation problem can be solved with a space-stabilized attitude and heading reference system (AHRS) of reduced configuration tailored to the railway conditions [3, 4]. Unlike SINSes with complete sets of sensors, this AHRS can be based on one or two FOGs aided by accelerometers and other data sources such as odometer, satellite receiver, system of motion sensors (or optical system). These systems feature a much simpler design and lower cost while maintaining the required accuracy.

Using a sole odometer to localize the measurement results does not provide satisfactory results because of its errors. Integrating the odometer, SINS and receiver readings offers highly accurate referencing of diagnostic results to the traveled track coordinate [5, 6]. Odometer readings are updated using navigation system data.

The system provides the measurement of track geometry and accurate localization of the measurement point using the geographical coordinates (latitude and longitude) and attitude parameters (roll, pitch and heading). Therefore, results from multiple runs can be used to form a GIS database.

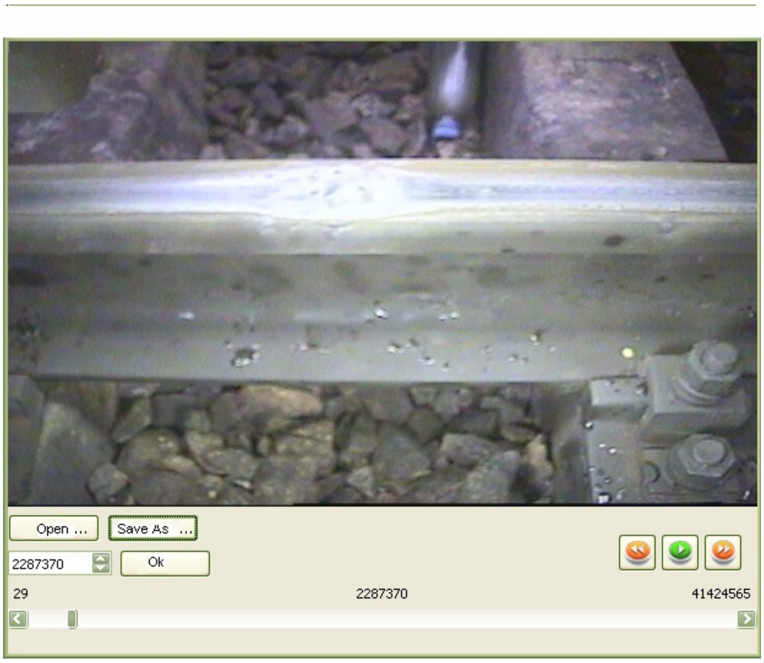
## Software

The software performs the following functions:

- collects, synchronizes and processes data from hardware components;
- checks the system serviceability;
- records the results on media.

User interface supports OS Windows and provides the following:

- real-time graphical representation of track parameters and identification of revealed defects using video system. The track parameters to be displayed are selected by the user;
- estimation of track parameters according to the normative documents;
- registration of measurement results in a form of defect reports indicating the defect position, depth and length, and the date, road segment and speed.




Video system screen shot (squat)

## References*

* For registered users only, download file from http://www.zgoptique.ch/reg/railwaytrack_refs.pdf

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## Technical Data

| Track parameters | Accuracy |
|---|---|
| **Track geometry** | |
| track gauge, longitudinal level, alignment, superelevation, twist | 0.5 mm |
| curvature | 0.00005 $m^{-1}$ |
| track coordinate (with satellite receiver and odometer aiding) | 0.2 m |
| **Rail surface defects** | |
| corrugations, squats, wheelslip surface defects, wheelburns | 1 mm |
| **Navigation and attitude parameters** | |
| geographical coordinates (latitude and longitude) | 1 m |
| heading | 0.1 deg |
| roll and pitch | 0.07 deg |
| **Train dynamics and driving comfort** | **Range** |
| rate | ± 200 °/s |
| acceleration | ± 20 g and ± 50 g |

## Operating Parameters

| | |
|---|---|
| Speed range | 5 … 350 km/h |
| Data output rate | 1 kHz |
| Readiness time | max 15 min |
| Continuous operation | unlimited |
| Operating system | Windows / Linux |
| Interface | USB, Ethernet, etc. |
| Supply voltage | 220 V AC |
| Power consumption | <50 W |
| Operating temperature | -40° C …+60° C |

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