Semi-automatic measuring device for survey selected parameters of the railway roads

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Keywords: railway roads, monitoring, multi-sensor device

SUMMARY

Many countries are building new railway roads or extending the existing ones to reduce congestion and improve the urban environment. Such connections are related to the issues of operational safety of rail vehicles. An important factor influencing this safety is the reliable track infrastructure on which the vehicles move.

Therefore, monitoring the geometric condition of the railway roads is an investment aimed at more efficient damage control and optimisation of the repair and maintenance schedule, allowing to minimise emergency interventions limiting the efficiency of the transport system to only planned repairs.

The paper authors described a developed multi-sensor device for acquisition, processing, and assessing the technical state of selected parameters of the railway roads. The choice of optimal sensors consisted in finding a balance between the usefulness, the possibility of data integration and the final price of the device. The sensors selected in this way allow one to carry out the tasks of a traditional measuring trolley and railway draisines in one device. Furthermore, surveying devices measure all technical parameters in one pass, significantly reducing the time. The results of the development work have to increase the reliability of the current track infrastructure, which will improve the comfort of passengers and their safety.

SUMMARY

Wiele krajów buduje nowe drogi kolejowe lub rozbudowuje istniejące, aby zmniejszyć zagęszczenie ruchu i poprawić środowisko miejskie. Takie rozwiązanie związane jest z zagadnieniami bezpieczeństwa eksploatacji pojazdów szynowych. Ważnym czynnikiem wpływającym na to bezpieczeństwo jest niezawodna infrastruktura torowa, po której poruszają się pojazdy.

Dlatego monitorowanie stanu geometrycznego dróg kolejowych jest inwestycją mającą na celu skuteczniejszą kontrolę uszkodzeń oraz optymalizację harmonogramu napraw i konserwacji, pozwalającą na zminimalizowanie interwencji awaryjnych ograniczających wydajność systemu transportowego tylko do planowanych napraw.

Autorzy artykułu opisali opracowane urządzenie wieloczujnikowe do akwizycji, przetwarzania i oceny stanu technicznego wybranych parametrów dróg kolejowych. Wybór optymalnych czujników polegał na znalezieniu równowagi pomiędzy użytecznością, możliwością integracji

danych a ostateczną ceną urządzenia. Tak dobrane czujniki pozwalają na realizację zadań tradycyjnego wózka pomiarowego i drezyn kolejowych w jednym urządzeniu. Ponadto urządzenia geodezyjne mierzą wszystkie parametry techniczne w jednym przejściu, co znacznie skraca czas pomiaru terenowego.
Wyniki prac rozwojowych mają na celu zwiększenie niezawodności obecnej infrastruktury torowej, co poprawi komfort pasażerów i ich bezpieczeństwo.

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1. INTRODUCTION

Many countries are introducing new railway lines and extending existing ones to reduce congestion and improve the urban environment. Such development is related to the issues of operational safety of rail vehicles. An important factor influencing this safety is the reliable track infrastructure on which the vehicles travel. The effects of the conducted development works will translate into the reliability of the current track infrastructure, which will directly affect passengers' comfort and safety. Railroads also reduce the level of exhaust gases, for example, in the Wroclaw (Poland) agglomeration and, therefore, reduce smog. It is crucial from the point of view of the current policy of the European Union. More reliable tram systems in the city will contribute to the growing interest in this form of transport, and thus it will be possible to develop the tram network in cities further.

The project plan aligns with the Smart City idea, which states that investments in human and social capital, supported by the development of modern infrastructure, are the foundation of sustainable economic growth and the basis for a high quality of life. But, on the other hand, the individual elements must complement each other and cooperate [3], [14], [15]. For example, Wroclaw strives to achieve this balance by investing in good infrastructure, a friendly environment and transport.

Therefore, reliable information about the technical state of the rail track infrastructure is needed. However, a classic survey is slow and needs improvements, especially regarding speed and density of information. Therefore, some development works and tests were performed in cooperation with GEOSTER company under the MOZART project organised by the Wroclaw Academic Center.

2. SURVEYS OF TRAM TRACKS

Depending on the measured geometrical quantities, stocktaking measurements of railways can be carried out using various technologies [5]. However, each of the geodetic measurement methods has its advantages and disadvantages, so it is worth proposing your measurement system solution adequate to the functional and accuracy needs of the track. Our work aims to create a measuring device for collecting information about the geometrical condition of the railroad.

2.1 Technical guidelines

A tram track can be defined as a set of two parallel railways, which, together with other elements, constitute a structure adapted to steer rolling stock wheels and carry loads of this rolling stock [12]. Currently, the Polish law does not contain any regulations and instructions applicable to measurements and track condition assessment. In the Act of March 28, 2003, on rail transport [16], you can find only a definition of a tram line and provisions for determining the location of tram lines located outside public roads. Tram tracks are built based on the Act of April 10, 2003, on special rules for preparing and implementing investments in public roads [17]. The primary document describing the technical requirements to be met by a tram track is the Regulation on technical conditions to which public roads and their location should correspond [13].

Due to the lack of detailed regulations defining guidelines for the design and diagnostics of tram tracks, infrastructure managers use the Technical Guidelines to design and maintain tram tracks [18]. This document was created in 1983 and had no legally binding status. Considering the year the document was written and the development of technology and design solutions since its publication, most of the solutions presented are obsolete nowadays. Another essential document is the Id-14 instruction [9], which concerns the railway track, not the tram track. In assessing the geometric condition, one can also follow the guidelines for the measurements of crane tracks, which are described in the relevant standards [11], [1].

2.2 Measurement methods of railways

Contact and non-contact devices can be used to inventory the tram track. The first measures under load, i.e. in the same conditions in which the track is used by passing trams. Non-contact devices are installed in the vehicle as cameras and laser beams, which enable continuous measurement of rails [2]. Another way to assess the condition of the track may be to analyse the ground. According to technical requirements, some classification was developed in Gdansk after analysing the material from their survey in which the substrate was measured and assessed [6].

<u>A classic survey using total-station</u>

Tachometry is currently used in railroad measurements to achieve accuracy through precise instruments. This method is used to prepare situational and height maps for railway purposes, implement measures to construct new lines and railway facilities, and as-built and inventory measurements. Inventory measurements are related to the modernisation and maintenance of tracks, and their task is to demonstrate the geometric parameters of the tracks. In the tachymetric survey, to determine the geometry, a reflector must be used, placed on a special adapter set on the inner edge of the measured rail track [4].

<u>Laser scanning</u>

The accuracy of measurements using the laser scanning method is significantly influenced by: the type of surface (intensity of signal reflection) and its location in relation to the scanner, scanning resolution, and the prevailing weather conditions. The available computer programs for laser scanning data processing make it possible to perform many different analyses based on the obtained 3D models. Hence, this method works well in inventory or diagnostic measurements of tracks. Furthermore, terrestrial laser scanning allows you to get information on, among others. For example, track, turnout geometry, track surface, gauge and track position can be placed in relation to the other infrastructure [4].

Track gauges

In the nineteenth century, track gauges were built and initially measured only the track spacing. Currently, they can be divided into classic and electronic. One of the solutions is to use the Leica TS16 total station with the LTrack module dedicated to tracking measurements. The Ltrack system records data in real-time, thanks to which it is possible, through the "Measure the rail" and "Stake track" applications, to view the obtained data in a three-dimensional image. Such measurement allows for controlling the survey and eliminating gross errors. The results of the measurements are the coordinates marked in the places where the bogie stops to measure the trolley, which, undergoing further studies, allow to obtain the geometrical parameters necessary to assess the condition of the tracks [8].

Draisines

A modern diagnostic vehicle enables a comprehensive assessment of the railway line. With the help of lasers, the geometry of the track and rails is precisely measured, and the condition of the trail is checked. The systems test the operation of devices responsible for the safe running of trains. In addition, it is possible to perform diagnostics of the traction network. Special sensors located in the draisine reflect the train's movement. Based on the obtained data, PLK experts detect faults that may affect the quality of train running, i.e. the comfort of passengers' travel [10].

3. Semi-automatic measuring device

The railroad measuring device (Fig. 1) developed by the MOZART project consists of:

- • a measuring trolley designed to measure tram tracks,
- Terrestrial laser scanner Leica ScanStation P40,
- linear displacement sensor PTx from Peltron,
- GNSS receiver NovAtel OEM615™,
- inertial measurement unit IMU STIM300 from Sensonor.

The integration of inertial data with a terrestrial laser scanner is based on direct georeferencing. It consists of transforming points - first, the transformation from the local scanner system to the IMU system and then to the temporary topocentric navigation system. The next step is rotation and translation to the geocentric system. This procedure makes it possible to calculate positions in-plane systems valid in a given place [7]. In addition, the use of a linear displacement sensor makes it possible to obtain the rail spacing with an accuracy of 0.1 mm. The data obtained with this device are device trajectory, data from the linear displacement sensor and cross-sections from the scanner. Finally, data integration is based on synchronisation using timestamps in the form of a PPS signal and NMEA message.

Fig. 1. The developed measurement device during the survey.

4. Discussion

The survey was performed on Mickiewicza street and Marino loop. Collected data were processed in Inertial Explorer 8.90 as a tightly coupled solution. In both cases, we got precise and solid trajectory, most time better the 1cm estimated accuracy. The separation between forward and backwards was better than 5cm. Also, the solution about attitude was accurate. Some visualisation of the achieved accuracy was presented in Fig 2. (position) and Fig. 3. (attitude) for Mickiewicza street. Fig 4 (position) and Fig. 5. (attitude) present results for Marino loop.

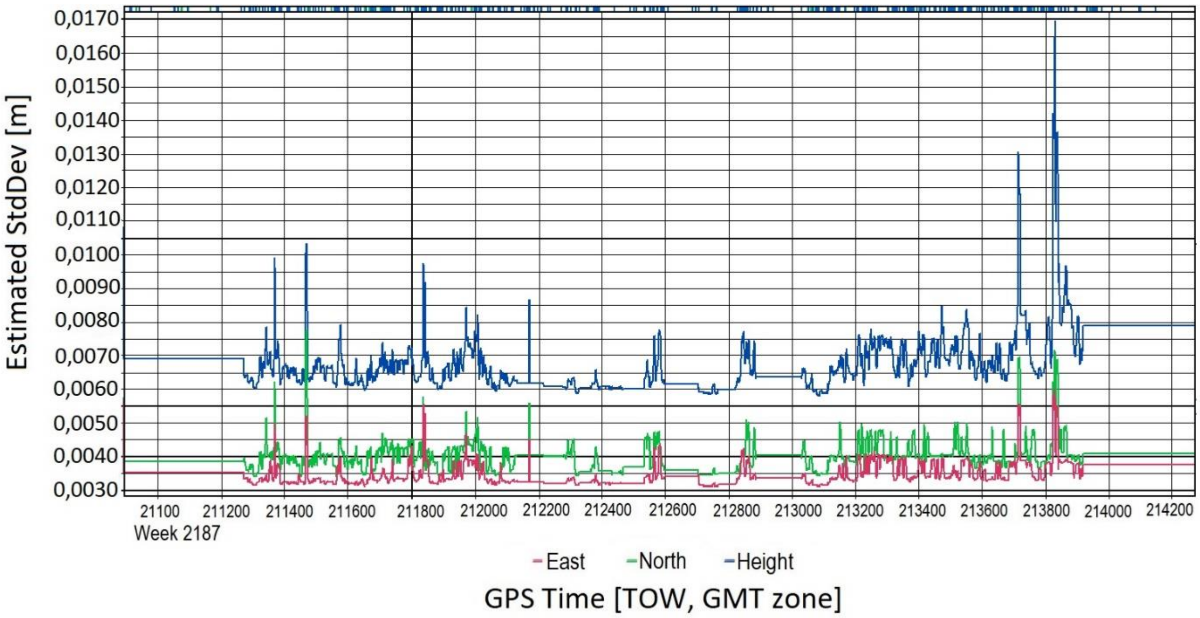

Fig. 2. Mickiewicza - estimated position accuracy plot.

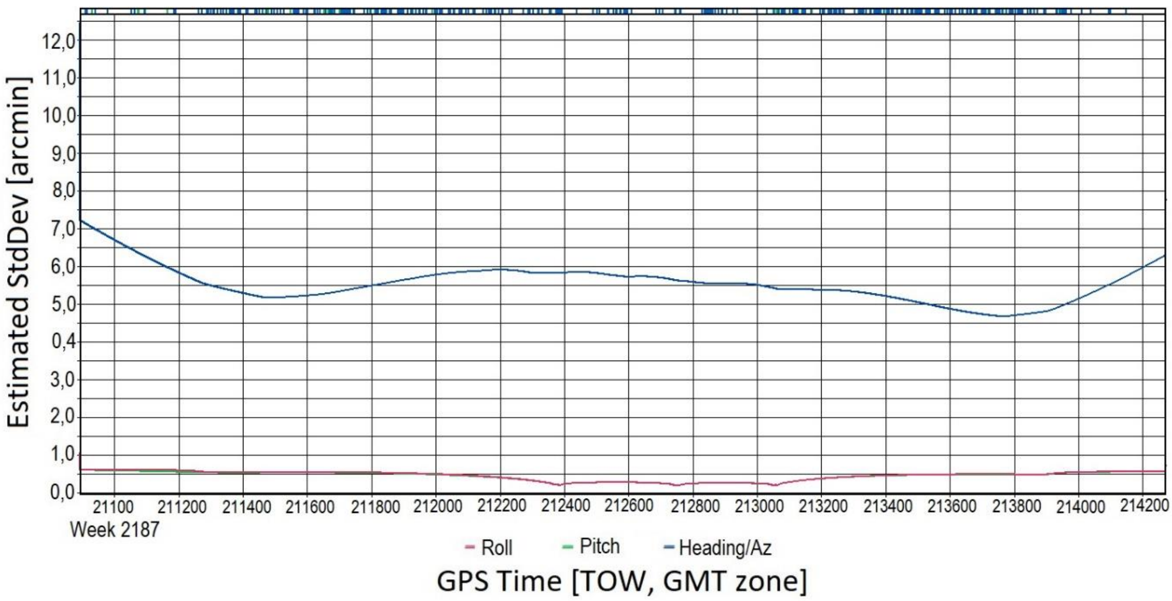

Fig. 3. Mickiewicza – estimated attitude accuracy plot.

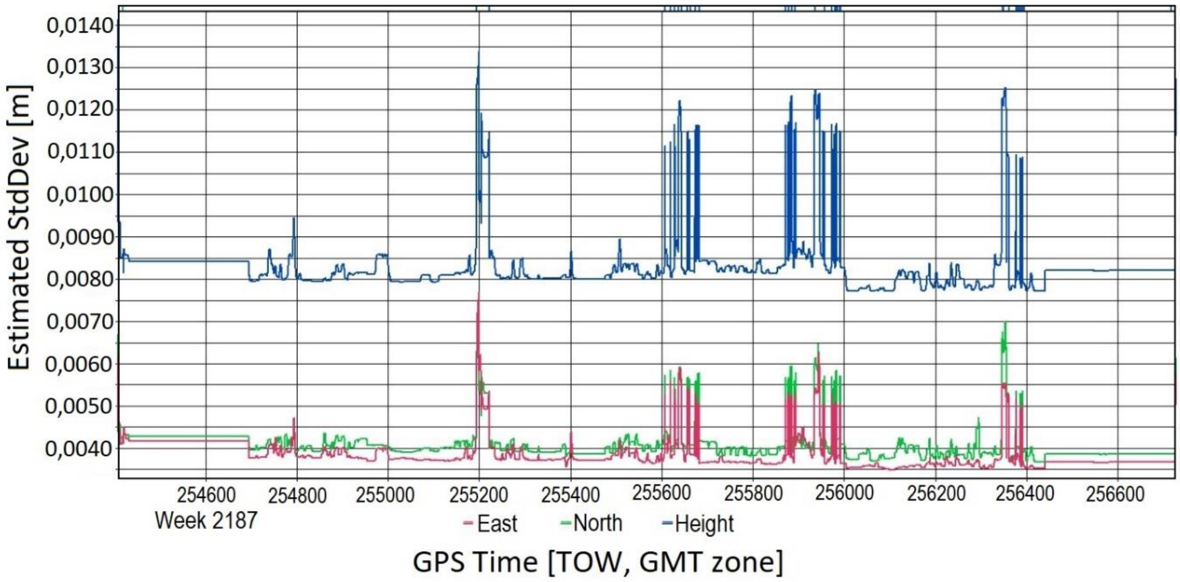

Fig. 4. Marino loop - estimated position accuracy plot.

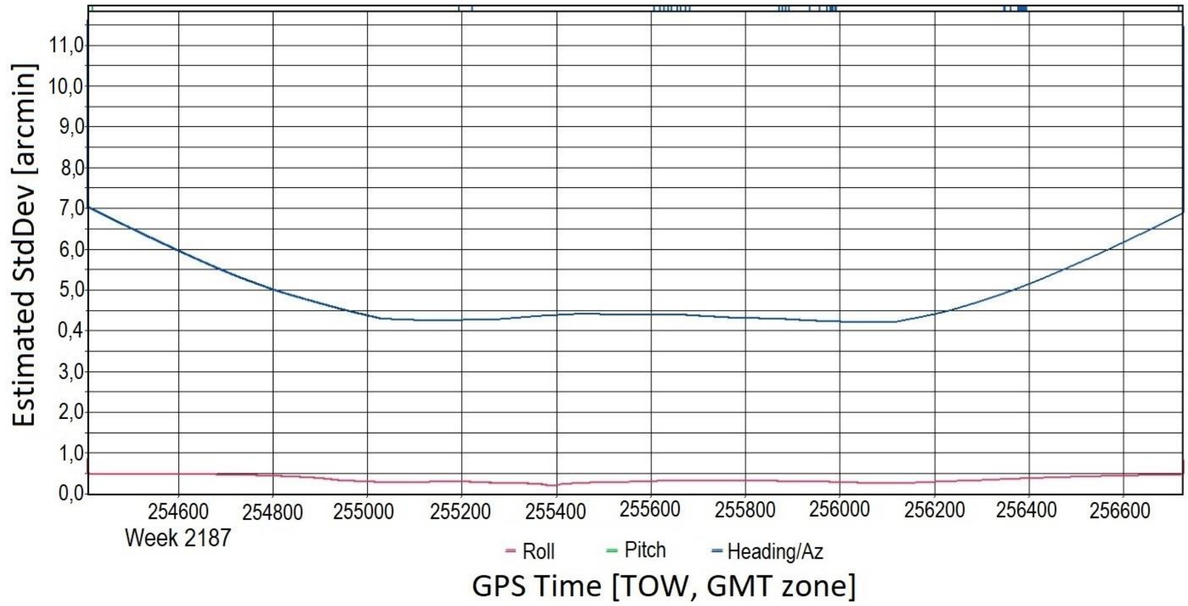

Fig. 5. Marino loop – estimated attitude accuracy plot.

Next, we compare the difference between the classic survey using total-station and the developed device. Then, finally, in the same profiles, we reach the difference between the standard spacing in Poland (1,435 m), which is the same for tram and rail and the field survey, which gives similar results differing from 2-5 mm in some cases more even 20 mm. It was caused by not having perpendicular profiles to track in a classic survey.

Also, we calculate the five-parameter defect (1), which is a relative, i.e. a geometrically changing with the speed of trains, an indicative measure of the track condition. The dependency determines it [9]:

$$W5 = 1-(1-We)(1-Wg)(1-Ww)(1-Wz)(1-Wy) \quad (1)$$

where:
We – width defectiveness,
Wg – cant defectiveness,
Ww – defectiveness of twist,
Wz, Wy – are the arithmetic means of the defectiveness, the corresponding vertical and horizontal irregularities determined from the defectiveness of the left and right rail tracks.

The classification of W5 parameter based on value is presented in table 1 - the smaller value of this factor, the better the shape of the track is [9].

Table 1. Limits of the overall geometry of the track [9].

Geometric evaluation of track condition	**Defect value W5**
New tracks	$W5<0,1$
Tracks in good geometrical condition	$0,1<W5\leq 0,2$
Tracks with sufficient geometrical condition	$0,2<W5\leq 0,6$
Tracks of unsatisfactory geometrical condition	$W5>0,6$

The values of the acceptable defectiveness are distinguished in 3 classes of track condition assessment (A, B and C). Table 2 presents values of W5 factor for the test object.

Table 2. Summary of W5 values in individual classes.

W5	Classes C	Classes B	Classes A
Developed device	0,473	0,645	0,864
Tacheometer	0,462	0,630	0,850

In both cases, the values of the W5 parameter are similar, and the shape of the track is insufficient geometrical condition. The trail is not used in regular transportation, and only in emergency detours tram can go, but they must lower their speed by 10-15 km/h. It is worth noting that we assess the condition of the tracks based on an index used in railways. They are not adequate to the requirements of the tram track.

5. SUMMARY AND CONCLUSIONS

The project aimed to develop a multi-sensor device and a method for collecting and processing spatial data to assess the possibility of using them to determine railways' technical conditions (data integration, analysis and interpretation).

Systematic track inventory is necessary to manage the tracks used in Wroclaw's urban rail transport system. Up-to-date information on track conditions will help improve infrastructure maintenance, translating into lower operating costs. The project concerned the implementation of a measuring device for collecting information about the geometric condition of the railroad.

Inertial solution for track survey is interesting devices, and the current state of technology provides tools for precise surveying in motion. However, the tests confirmed the inertial device's usability and obtained accuracy compared to traditional surveys.

The research was developed in cooperation with GEOSTER Sp. z o.o. as part of the MOZART project organised by the Wroclaw Academic Center, Wroclaw City Hall.
Partnership topic: "Multisensor device for measuring railroad parameters with software**.**"
The survey results were used in the diploma theses of Martyna Tomaszewska „Inventory of the tram loop track using an innovative device measuring the geometry of railroads" and Aleksandra Totoń „Inventory of a section of tram track using an innovative device measuring the geometry of railroads".

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BIOGRAPHICAL NOTES

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