IOP Conf. Series: Journal of Physics: Conf. Series **870** (2017) 012010 doi:10.1088/1742-6596/870/1/012010

DMI measurements impact on a position estimation with lack of GNSS signals during Mobile Mapping

K Bobkowka[1],G Nykiel[1], P Tysiąc[1]

[1]Department of Geodesy, Faculty of Civil and Environmental Engineering, Gdansk University of Technology, Gabriela Narutowicza str. 11/12, 80-233 Gdansk, Poland

pawel.tysiac@pg.gda.pl

Abstract. Nowadays, Mobile Laser Scanning is common in use in addition to geodesy measurements. The data which are provided by the system characterizes with high precision and flexibility. To precise mapping, the accuracy of the data should be maintained. In Poland, according to the minister's dispositions, the accuracy of the data should not exceeded 10 cm. With fully operated system it is easy to uphold, but there is a situation when a signal from an INS is not enough to preserve it. This paper is presenting the solution of a DMI use in Mobile Laser Scanning measurements as the support for position estimation during lack of satellites signal situation when the vehicle with the platform was entered the tunnel. To comparison the results a several of entrances was performed. This research helps understand the use of DMI in mobile data acquisition in different acquiring situations.

1. Introduction
Mobile Laser Scanning data provides data which characterizes with high accuracy, precision and point density. Nowadays it is very important to gather the spatial information very fast to minimalize the cost of the measurements which could be noticed in traditional geodesy measurements methods. It is very important to maintain the continuously of the data accuracy, because of the project's assumptions where the accuracy was estimated [1]. Sometimes it is very problematic, considering the field shutters like high buildings, trees or the change of DOP (dilution of precision) factor [2], [3], [4]. For this study, the lack of satellites was taken in consideration in case of measurements in a tunnel. To maintain the position estimation, the GNSS/INS was used with DMI (distance measurement instrument) device as an additional equipment. This device measures wheel revolutions of the vehicle. The characteristic of obtaining data slows the growth of the inertial error which influence on the quality of the data. We present comparison of measurements in obstructed area, when DMI was in use and when DMI was excluded. The measurements were performed during laser scanning scanned object which was a tunnel under the Martwa Wisla in Gdansk. The use of laser scanning for this type of building is quite wide. This measurement method can be used, for example, for rockmass classification [5] or for tunneling monitoring [6]. It is also used to detect cracking of concrete objects [7], [8], [9], [10].

2. Experiment realization method
The data was collected by using Riegl VMZ-400 system, provided by Apeks Company based in Gdansk, Poland. Before the experiment realization measurements, the proper calibration system should be performed. It consists of measuring the offsets between the phase center of the device and DMI,

GNSS/IMU [11] and proper alignment of the angles roll, pitch and yaw. To proper align these angles, it is required to perform the static and dynamic alignment, where the static alignment refers to 5 minutes spatial data gathering through GNSS receiver and dynamic to accelerate and to decelerate the vehicle where the system is placed. That processes are crucial in addition to have proper alignment of points with expected accuracy. For the realization of the experiment, a several passing through the tunnel was performed. The tunnel is 1400 meters long. In the beginning of the measurements, the availability of the satellites was good and after entering the tunnel signal was lost. The trajectory was aligned in two different ways in post-processing mode. First, when the system was fully operational (GNSS/IMU + DMI) and the second, when the trajectory was aligned without DMI. It helps the authors to understand the phenomena of DMI impact on the point cloud records accuracy and precision and achieve the main goal of this paper which is showing the impact of the DMI measurements on mobile mapping.

3. Positioning results

The main goal of this paper is to show the crucial role of using the DMI device when the GNSS signal is lost. In Figure 1 standard deviations (STD) of position and angles derived from GNSS/IMU measuring system are presented. During the measurements time 7 passes were made through the tunnel. This is clearly seen in the figure, because position STD values increased. The highest values were obtained for North and East component of the position. However, it is worth to notice, that when the DMI device was used STDs decreased by about 25%, 45% and 25% for North, East and Up component respectively. In Fig. 1 STD of angles derived from IMU device are also presented. It can be seen that usage of DMI has not significant improvement in case of STD of roll and pitch angles. Values obtained with and without DMI are very similar. Interesting results are visible in case of heading angle. It is seen that usage DMI measurements decreases STD values by approximately 10%. However, what is seen in the figure, improvements occur throughout the duration of the measurements, not only when the tunnel was scanned.

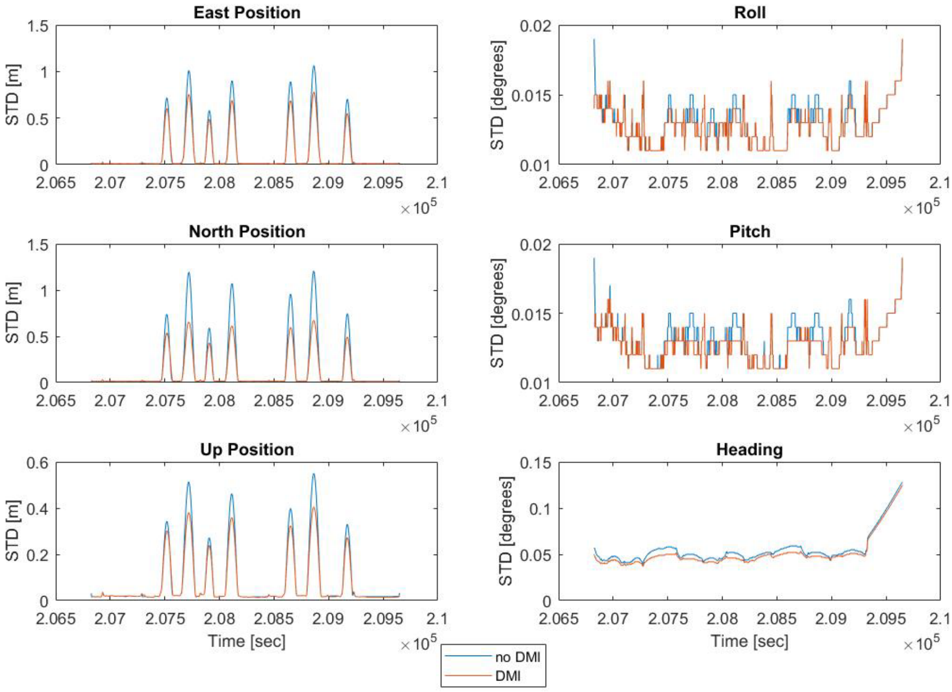

Figure 1. Standard deviation values for position (left) and angles (right) measurements derived from GNSS/IMU system (orange line: with DMI, blue line: without DMI).

In Table 1 and Table 2 numerical values for sample passage through a tunnel are presented. The first record refers to situation when the platform was on the open space where satellites geometry was good and DOP factor had low value. There is no significant differences between measuring the system with or without the DMI. The second one is presenting entering the tunnel where availability of the satellites were constrained because the appearance of wall shutters, housing the tunnel. The third and the forth are presenting STD of a position estimation in a half way of a tunnel (the third) and at the end (the forth). As is seen the values are significantly high in order to maintain the accuracy and precision up to 10 cm. However, as we mentioned above, usage of DMI device together with GNSS/IMU. In Table 2 it is also seen impact of DMI of the heading angle measurements, which does not matter whether the measurement took place, in or before the tunnel. Thus, we conclude that be an effect of the distance measurement indicator influence on the heading angle value.

Table 1. Comparison of position (in topocentric coordinates) standard deviations (in meters) between solution when DMI was used and was not.

No.	GPS time	East STD DMI	East STD no DMI	North STD DMI	North STD no DMI	Height STD DMI	Height STD no DMI
1	**207230.52026**	0.014	0.009	0.019	0.014	0.012	0.019
2	**207561.56578**	0.080	0.052	0.093	0.048	0.092	0.073
3	**207694.94101**	0.495	0.636	0.493	0.822	0.313	0.412
4	**207722.55106**	0.752	1.008	0.653	1.190	0.379	0.509

Table 2. Comparison of Roll, Pitch and Heading standard deviations (in degrees) between solution when DMI was used and was not.

No.	GPS time	Roll STD DMI	Roll STD no DMI	Pitch STD DMI	Pitch STD no DMI	Heading STD DMI	Heading STD no DMI
1	**207230.52026**	0.012	0.012	0.012	0.012	0.042	0.046
2	**207561.56578**	0.013	0.013	0.013	0.013	0.050	0.056
3	**207694.94101**	0.013	0.014	0.013	0.014	0.045	0.050
4	**207722.55106**	0.013	0.015	0.013	0.015	0.045	0.050

4. Mobile mapping results

Presented positioning results should have impact on mobile laser scanning. In order to verify this, we consider point cloud quality obtained during measurement with and without DMI. First, the situation where the DMI device on the open space with good DOP was taken on consideration. The section of the tunnel before enter is presenting as a point cloud in Figure 2.

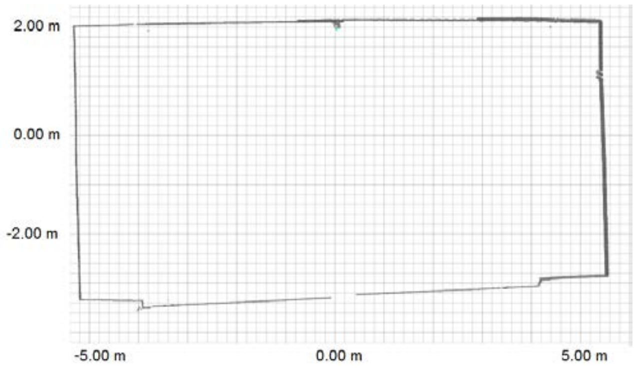

Figure 2. The section of the tunnel when the system was fully operational.

As its seen on the figures, the data was align correctly, based on the structure of the point cloud. The position error growths when the vehicle with the platform entered a tunnel. The authors present the results of the experiment when the GNSS signal was lost for more than 2 minutes. Figure 3 shows the result of fully operational mobile mapping system after losing the GNSS signals for more than 2 minutes, which (based on speed limits in Poland) equals 1.4 km. The difference between three records is up to 40 cm, but it has to be mentioned that two of them are aligned with the error, not exceeded 10 cm. In Figure 4, the point cloud presenting the results of measurements when the DMI was not used is shown. This solution is very important in case of placing the mobile platform on a vessel [12] and it is crucial to understand the phenomena of the measurements in order to increase the accuracy with no DMI solution in mobile mapping.

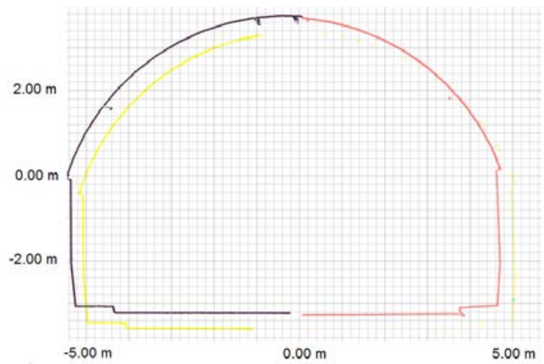

Figure 3. The three point cloud records, showing the align errors fully operational systems (GNSS/IMU + DMI).

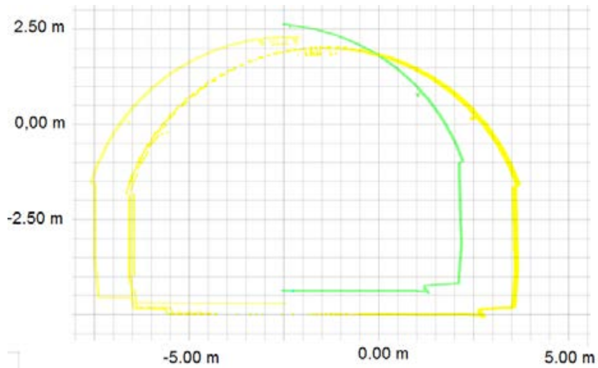

Figure 4. The three point cloud records, showing the align errors of the system without DMI.

In Figure 5 trajectories derived from the mobile scanning platform are shown. By red color we marked trajectories obtained with GNSS/IMU + DMI system, and by green color when DMI was excluded. On left side of the figure, three trajectories measured during passage the tunnel are presented. The differences between solution with and without DMI are clearly visible and reach even a few meters. This is caused by positioning incompatibilities, which we described. As it is seen, outside the tunnel the differences between trajectories can be neglected.

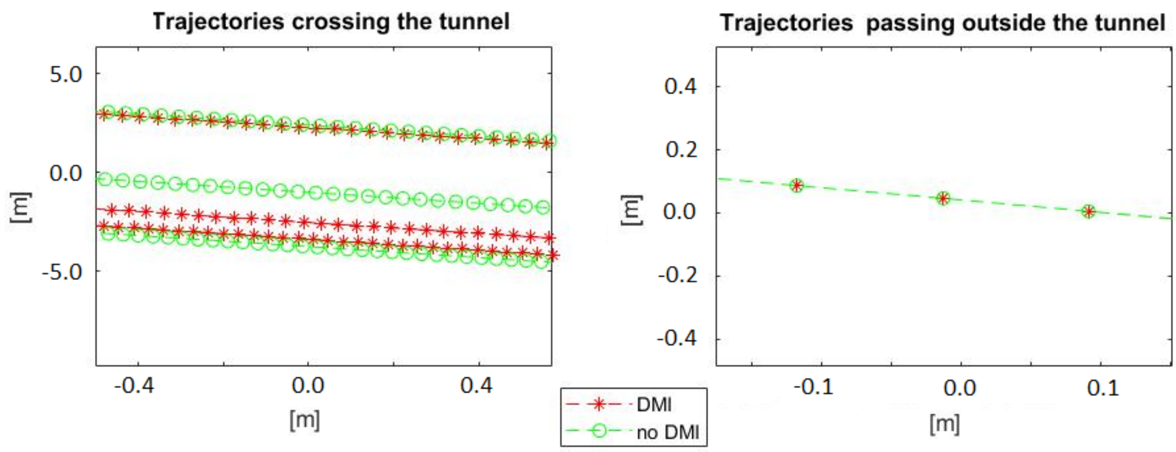

Figure 5. Trajectories derived from the mobile scanning platform during crossing the tunnel (left) and outside the tunnel (right).

5. Conclusions

Mobile mapping is still new spatial data acquisition method and have a lot of constrains, which allows to develop new measuring solutions which could be successfully used in geodesy and cartography or even civil engineering. We presented impact of DMI measurements on the mobile mapping in reference to lack of the GNSS signals. We proved, that a distance measurement indicator device is crucial in use when the GNSS signals is lost. We obtained that DMI can increase the precision of position by about 25% in obstructed area. Also, some improvements of heading angle derived from IMU were observed. Usage of DMI decreased its STD by about 10% during throughout the measurement period.

To check how the obtained positioning results impact on the mobile mapping, we presented comparison of the point clouds and trajectories. We can stated that differences of trajectories between measurements with DMI and without DMI can reached up to few meters during passage the tunnel. However, even the results of the trajectory STD were up to 1 meter with the use of the DMI, the precision of the point cloud does not exceed 40 cm in reference to three records, two of them, are align with an error which does not exceed 7 cm.

It has to be mentioned that mobile systems could be used when there is no possibility to mount the DMI (for example mobile platform, placed on a vessel [13]). In that case, a geometry of satellites is good, when a vessel ship on an open space, but when organize a measurements on the rivers, in a high urbanized area, the situation could be different [14], [15].

For the further research, the authors are going to improve the quality of the data, when the DMI could be used, but there will be lack of the satellites situation and when the DMI could not be used.

References

[1] Ogle J, Guensler R, Bachman W, Koustak M, and Wolf J 2002 Accuracy of global positioning system for determining driver performance parameters *Transp. Res. Rec. J. Transp. Res. Board* **1818** pp. 12–24.

[2] Jing H, Slatcher N, Meng X and Hunter G 2016 Monitoring capabilities of a mobile mapping system based on navigation qualities *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*, 12-19 July 2016, Prague, Czech Republic

[3] Nowak A 2016 Dynamic GNSS Mission Planning Using DTM for Precise Navigation of Autonomous Vehicles *J. Navig.*

[4] Nowak A 2015 The Proposal to 'Snapshot' RAIM method for GNSS vessel receivers working in poor space segment geometry *Polish Marit. Res.* **22** no. **4(88)**, pp. 3–8

[5] Fekete S, Diederichs M, and Lato M 2010 Geotechnical and operational applications for 3-

dimensional laser scanning in drill and blast tunnels *Tunn. Undergr. Sp. Technol.*, **25** no. **5**, pp. 614–628

[6] Yoon J S, Sagong M, Lee J S and Lee K S 2009 Feature extraction of a concrete tunnel liner from 3D laser scanning data *NDT E Int.* **42** no. **2** pp. 97–105

[7] Janowski A Nagrodzka-Godycka K Szulwic J and Ziolkowski P 2016 Remote sensing and photogrammetry techniques in diagnostics of concrete structures *Comput. Concr.* pp. 335–342,

[8] Janowski A, Jurkowska A, Przyborski M, Sobieraj A, Szulwic J, Wróblewska D and Wieczorek B 2014 Improving the quality of education through the implementation of the diplomas and group projects during engineering studies in cooperation with employers *EDULEARN14 Proceedings (2014)* pp. 1837–1843.

[9] Nagrodzka-Godycka K Szulwic J and Ziółkowski P 2015 Method of selective fading as a educational tool to study the behaviour of prestressed concrete elements under excess loading *8th International Conference of Education, Research and Innovation, ICERI2015 Proceedings*, 2015 no. **ISBN: 978-84-608-2657-6** pp. 472–479.

[10] Nagrodzka-Godycka K, Szulwic J and Ziółkowski P 2016 Accuracy improvement of the prestressed concrete structures precise geometry assessment by use of bubble micro-sampling algorithm *16th International Multidisciplinary Scientific GeoConference SGEM 2016* DOI: 10.5593/SGEM2016/B22/S10.102 pp. 799-806,

[11] Chen C, Liu H, Liu Y and Zhuo X 2013 High accuracy calibration for vehicle-based laser scanning and urban panoramic imaging and surveying system *Proc. SPIE 8917, MIPPR 2013 Multispectral Image Acquis. Process. Anal. 89170Y* doi:10.1117/12.2031466

[12] Burdziakowski P, Janowski A, Kholodkov A, Matysik K, Matysik M, Przyborski M, Szulwic J, Tysiac P and Wojtowicz A 2015 Maritime laser scanning as the source for spatial data *Polish Marit. Res.* **22** no. **4** pp. 9–14, 2015.

[13] Shi B, Lu X, Yang F, Zhang C, Lv Y and Min C 2017 Shipborne Over- and Under-Water Integrated Mobile Mapping System and Its Seamless Integration of Point Clouds *Mar. Geod.*, pp. 1–19

[14] Guan H, Li J, Yu Y, and Liu Y 2016 Geometric validation of a mobile laser scanning system for urban applications *2015 ISPRS International Conference on Computer Vision in Remote Sensing. International Society for Optics and Photonics* pp. 990108–990108.

[15] Kwoczynska B, Sagan W and Dziura K 2016 Elaboration and Modeling of the Railway Infrastructure Using Data from Airborne and Mobile Laser Scanning *2016 Baltic Geodetic Congress (BGC Geomatics)* pp. 106–115.