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QUALITATIVE ANALYSIS OF THE NOVATEL SPAN-CPT GPS RECEIVER ACCURACY WITH AND WITHOUT THE INERTIAL MEASUREMENT UNIT (IMU)

Summary

The altitude measurements and the error information provided by the Novatel SPAN-CPT GPS receiver are reliable under good GPS signal reception, however, the adoption of this system in the machine for renovation of open water courses will be affected by the utilization or not of the Inertial Measurement Unit (IMU) during bad GPS signal conditions. Taking as reference the measurements performed under good GPS signal conditions, this paper compares the measurements obtained under bad GPS Signal conditions with and without IMU corrections.

PORÓWNAWCZA ANALIZA DOKŁADNOŚCI ODBIORNIKA GPS NOVATEL SPAN-CPT Z WŁĄCZONYM ŻYROSKOPEM (IMU) I BEZ JEGO UŻYCIA

Streszczenie

Dokładny pomiar wysokości przez odbiornik GPS SPAN-CPT jest zapewniony przy dobrym sygnale GPS. W złych warunkach terenowych dokładność może być zwiększona przez wykorzystanie dodatkowej korekty, pochodzącej od jednostki żyroskopowej (IMU). W artykule porównano wyniki pomiarów dokładności pozycjonowania z włączonym żyroskopem i bez jego użycia.

1. Introduction

The research made for this article is associated with the development of the project named: “Technology and new generation multi-task machine for regenerative shaping of opened watercourses” (No. WND-POIG.01.03.01-00-165/09). The project is realized by Industrial Institute of Agricultural Engineering (Poznan, Poland) within a framework of The Program Innovative Economy 2007-2013.

This machine will work inside drainage ditches and may be involved by dense vegetation. The adoption of a GPS receiver to assist the machine steering in order to obtain a proper slope of the ditch bottom relies on the accuracy of the altitude measurements provided by the receiver. The proper bottom slope for this kind of ditches is within the range of 2 – 5 ‰ [1], witch means that for each kilometer of the ditch linear length, the decline should be 2 – 5 m, therefore, for each 100 m of ditch linear length, the decline should be 0,2 – 0,5 m. This determines the minimum altitude positioning resolution of the machine on the ditch.

The Inertial Measurement Unit (IMU) provided in some GPS receivers (like the SPAN-CPT), correct the positioning measurements while the receiver works under bad GPS signal conditions. These conditions are affected by the obstacles (natural or artificial) that stand between the satellites and the receiver, like buildings, vegetation and hills. However, if the shortage of reliable GPS measurements is too long, the accumulation of calculation errors will gradually diverge the positioning from its real value.

The working conditions of the machine for renovation of open water courses will cause long periods (maybe several minutes) [1] of GPS signal shortage. Know how long it takes to the error of the measurements surpasses the maximum admitted error for the renovation of open water courses after loosing the GPS signals, is therefore the key for the decision of the adoption of the IMU corrections.

The ASG-EUPOS corrections obtained via GSM connection were known as fundamental to obtain an acceptable accuracy of the GPS measurements (0,03 m horizontal and 0,05 vertical using NAVGEO [4]), so its adoption was not in question.

2. Equipment description

The measurements were performed using a testing model on witch the system was built. The fig. 1 shows the approximate location of the GPS receiver in the model and its dimensions.

During the tests, the conditions of the GPS reception, IMU corrections and many other parameters were visualized and controlled using the Graphical User Interface (GUI) software provided by Novatel. To store the measurements during the tests, a microcontroller was used as data logger, saving the information in one SD memory card. The fig. 2 shows the connection scheme between the GPS receiver, computer, controller and the GSM modem.

3. Procedure

In order to compare the measurements made using the IMU corrections with those without, several static and moving tests were performed under different signal reception conditions.

In the static tests, the machine was placed over one specific point during several minutes and the measurements were performed under the following conditions:

- With IMU corrections deactivated: during several minutes, the receiver was subjected to intentional lack of GPS signal, to observe how fast it recuperates from a lack of signal.
- With IMU corrections activated: in the first tests, the receiver was left without any interference to observe the

variation of the measurements due to IMU corrections; finally, an intentional lack of GPS signal was caused to observe the divergence of the measurements.

In the moving tests, along a straight line and over a closed circuit, three different GPS signal reception conditions were simulated:

- Good GPS signal: The software of the receiver reports the reception of 7-8 good GPS signals and a very low error.
- Lack of GPS signal (used also in the static tests): A hand was placed over antenna, causing the loss of almost all GPS signals. The software reports only 1-2 satellites detected with bad signal.
- Bad GPS signal: An object (made of paper and small metallic parts) was placed over the antenna, causing the loss of some signals. The software reports 4-5 satellites, among those 1 or 2 have a good signal.

4. Static measurements

The fig. 3 shows the results obtained for the static measurements. For these tests, the receiver stayed in the same place and the following actions were performed:

- Tests without IMU corrections – The antenna were covered two times during each test.
- Test with IMU corrections and good GPS signals – the receiver was left without interference.
- Test with IMU corrections and lack of GPS signals – the receiver was left without interference during 2,5 min and then the antenna was covered.

The results show that when the GPS signal is good, the altitude measurements made without IMU corrections seem more stable. It's also visible that when the IMU correction is active, the variation of the altitude measurements is smaller than 15 cm, even after 2 min without a good GPS signal.

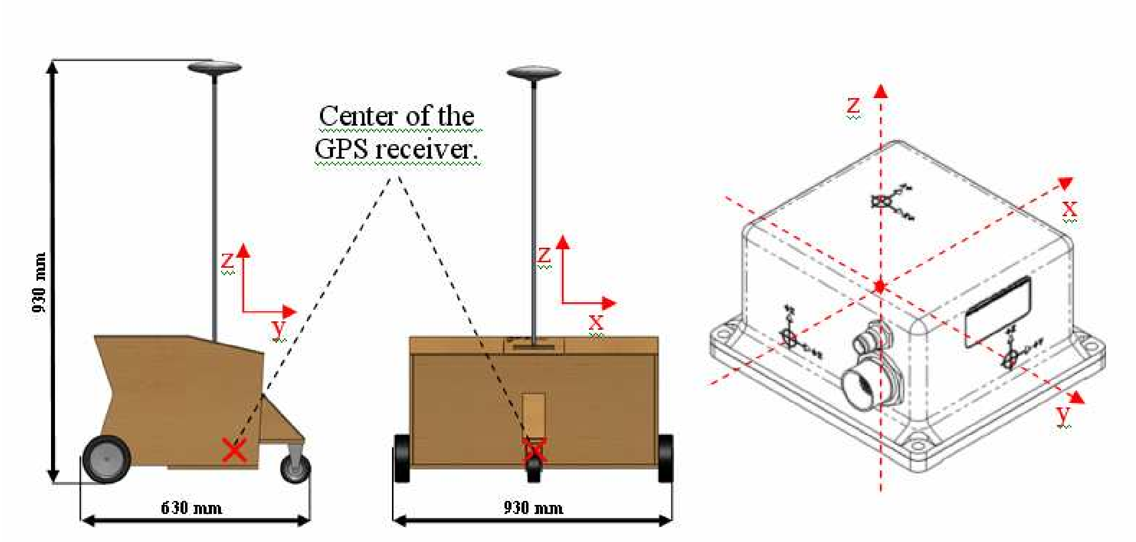

Figure 1. Testing model and the location of the receiver

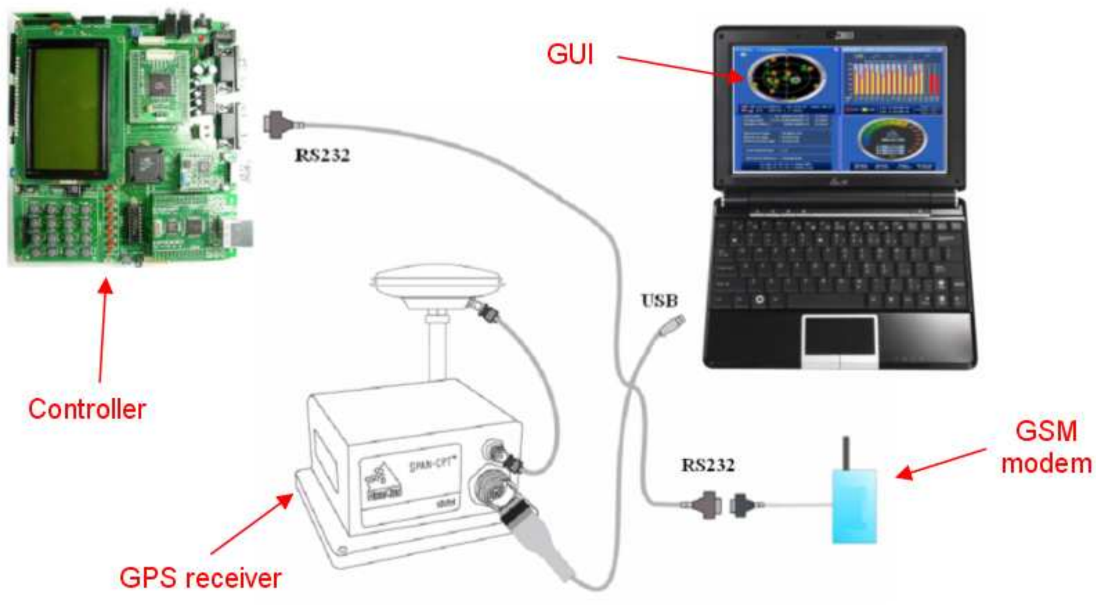

Figure 2. Connections of the GPS receiver

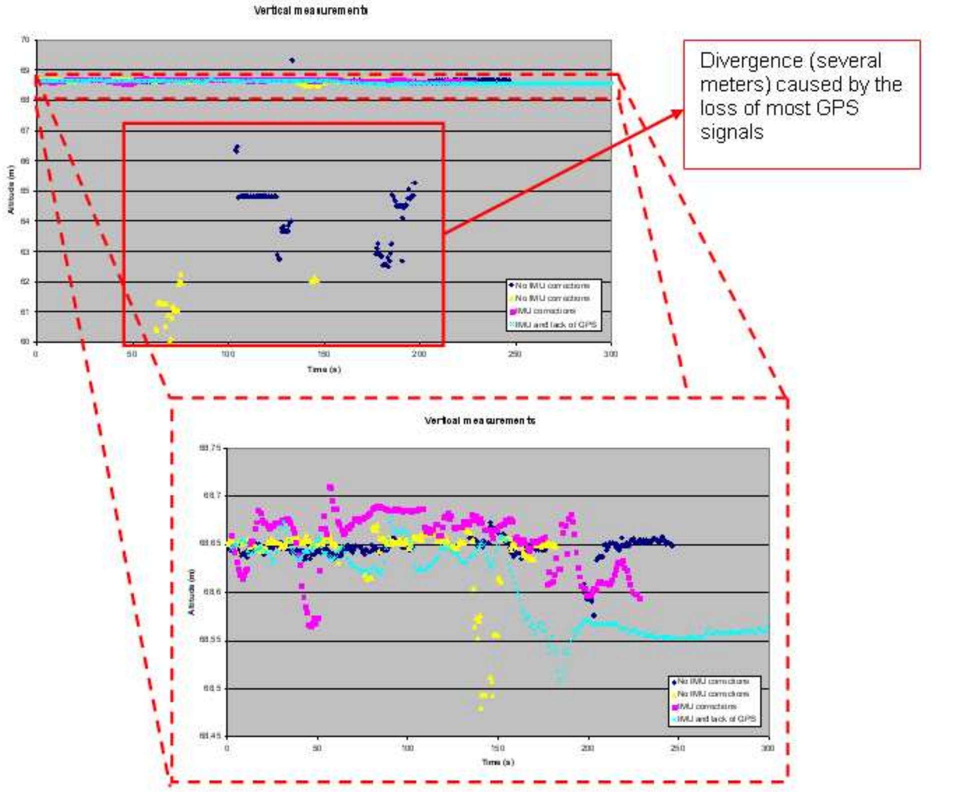

Figure 3. Results for the static measurements

5. Moving along one line

For the linear movement, a line was marked on the floor and the vehicle was moved along the line for each one of the tests.

Unlike the static measurements, the moving measurements, represented in the fig. 4, show that the error of the altitude positioning can pass the maximum admitted error even with 1 or 2 good GPS signals in less than one minute after loosing the optimal signals.

Meanwhile, the horizontal positioning when one or two good GPS signals are present seems to be within acceptable limits.

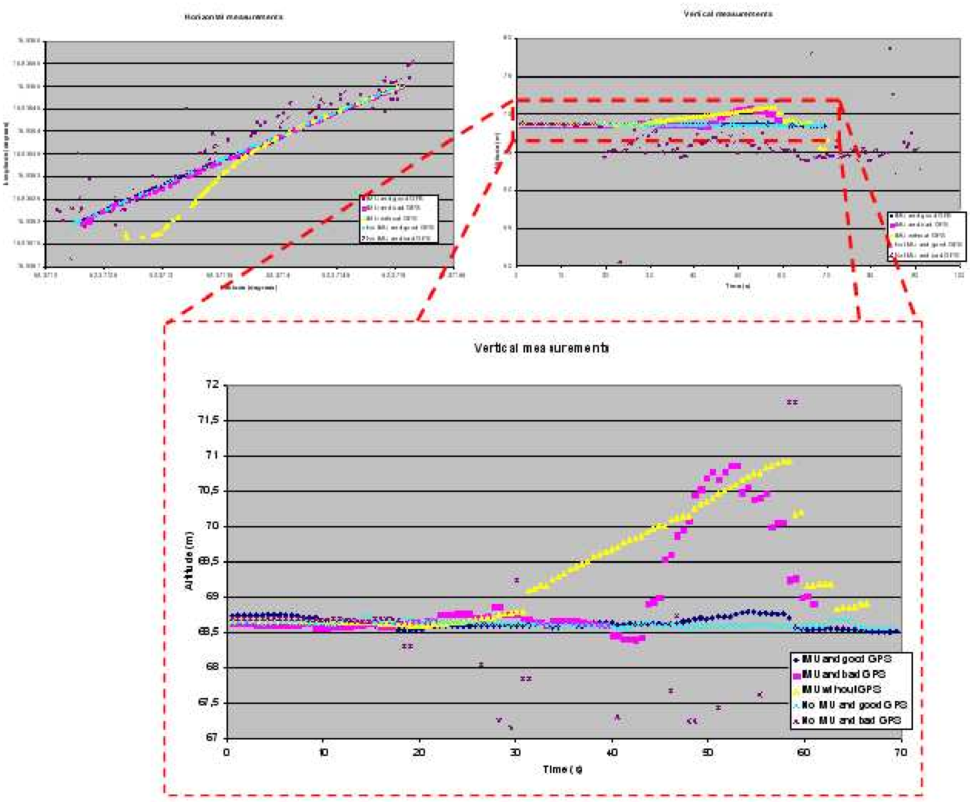

Figure 4. Results for the linear movement

The fig. 5 shows the division of the data in 3 areas of acceptability of the GPS signal:

- Good results – the position is less than 20 cm away from the reference – trustable positioning to obtain the proper slope.
- Bad results – the error is bigger, but the position is less than 2 m away from the reference – the positioning can serve as reference to the driver, however, to obtain a proper slope, a good positioning must be received periodically.
- Not acceptable – when the position is more than 2m away from the reference.

From this data, we can see that when the GPS signals were weak, even with the IMU active, the position starts to diverge from the good solution between 30 and 45 seconds after the lack of signal. In the other hand, this divergence exceeds the acceptable limits in less than 60 seconds.

Notice that the final convergence of the positioning made with the IMU activated (for bad or lack of GPS signals) is due to the removal of the obstacle from the antenna before switch off the acquisition.

6. Moving in a closed circuit

For these tests, a closed circuit was marked on the floor and the vehicle was moved along this path for each one of the tests.

The measurements made while moving the receiver (fig. 6), witch include proximity with a 2 floor building and several big trees, also show that the vertical positioning with the IMU activated and bad GPS signals doesn't suit the specifications of the ditch amelioration machine.

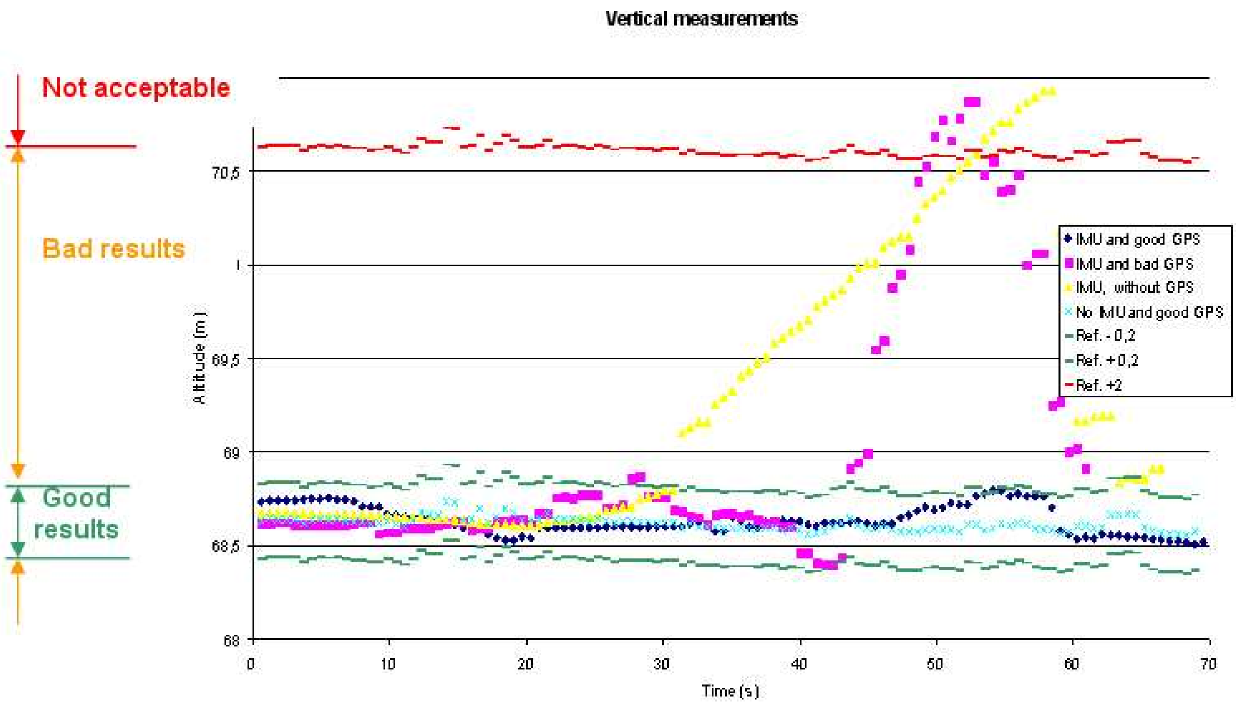

Figure 5. Positioning accuracy

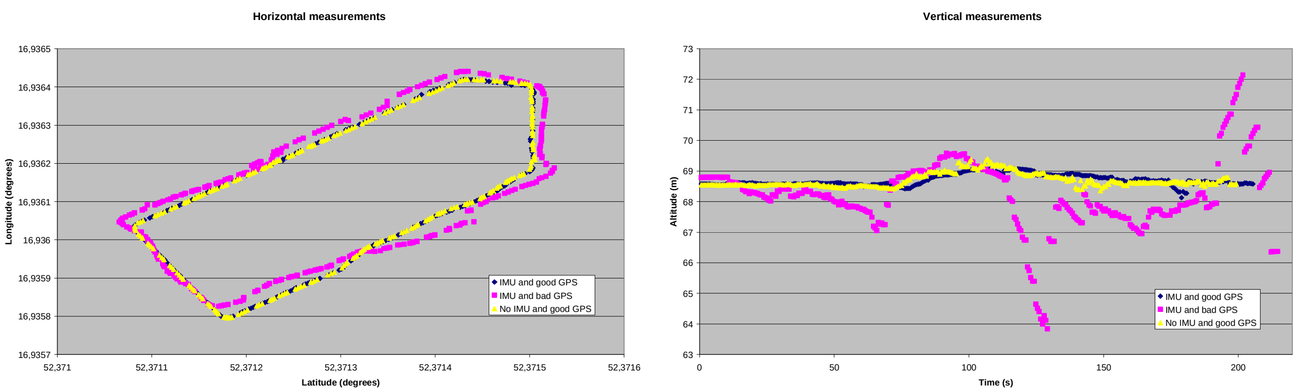

Figure 6. Results for the non linear movement

7. Conclusions

Exhaustive statistical research must be done if it will be necessary to have one approximation to the reliability of the positioning with the IMU active under bad GPS signal conditions. The amount of factors that affect the signal reception causes non repeatability of the accuracy tests, which brings more complexity to the seek of the accuracy values.

With these simple tests, it was possible to observe that the IMU is very useful to prevent the complete divergence of the positioning. Even during longer periods with bad GPS signals, the positioning (mostly the horizontal) stayed within some meters near the correct position.

However, this performance of the IMU can't guarantee the desired levels of the accuracy for the steering control of the machine.

Apparently, the better method to obtain the proper slope of the ditch bottom is to make very accurate measurements when the GPS signals are available, even if two consecutive measurements are relatively far from each other. If the user of the machine can guarantee the level of the ditch bottom in two points separated by some tens of meters, the flow of the water will naturally level the bottom in the intermediate path of the ditch.

8. Bibliography

[1] Rutkowski J. et al.: Pomiary cech geometrycznych rowów i kanałów oraz dokumentacja fotograficzna stanu jakościowego. Industrial Institute of Agricultural Engineering, 2009.

[2] Novatel: OEMV Family Firmware Reference Manual. Novatel, 2009.

[3] Novatel: SPAN-CPT User manual. Novatel, 2009.

[4] Ryczywolski M., Oruba A., Liończyk M.: The precise satellite positioning system ASG-EUPOS. GEOS, 2008.