GNSS-based navigation for the multipurpose field robot platform BoniRob to measure soil properties

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Abstract

The multipurpose field robot platform BoniRob offers a wide range of possible applications to be carried out by attaching different application modules called BoniRob-Apps. The Penetrometer-App can be used to measure penetration resistance, soil temperature and moisture. To be able to automatize the measurement process of soil properties a GNSS-based navigation for BoniRob has been developed with the Robot Operating System ROS. Network RTK-GNSS measurements are performed to estimate the position and orientation of the robot. The measurement process can be planned using GIS Software by defining the working area and desired measurement points. The measurement points could be approached with an accuracy (approach accuracy) better than 25 cm.

1. Introduction

The soil is one of the most important resources for agricultural production. Therefore, measurements and monitoring of soil parameters are of highest relevance in order for enabling a more resource efficient way of land use. Within this paper the authors present an approach of highly automatized soil property measurements, especially penetration resistance for soil compaction interpretations, using a penetrometer module [1] and an autonomous field robot platform [2] with RTK-GNSS.

2. Material and methods

Multipurpose field robot platform BoniRob and Penetrometer-App

BoniRob was developed by the AMAZONEN-Werke H. Dreyer GmbH & Co. KG, Robert Bosch GmbH and the University of Applied Sciences Osnabrück. It is designed as an multipurpose field robot platform into which different application modules – the so-called BoniRob-Apps – can be mounted. Hence, it is able to perform a variety of different tasks. Further information about the platform and its development idea can be found in [3]. The Penetrometer-App consists of a mechanical actuator, including a probing rod with defined cone (1cm², 60°) and a force sensor mounted on a vertical linear actuator which allows measuring the soil penetration resistance down to 80 cm from ground level. If the penetration resistance exceeds a certain force level threshold the measurement is stopped automatically. In addition the surface- moisture and temperature can be recorded using a second vertical linear actuator. A detailed description of the Penetrometer-App is given by Scholz et al. [1].

GNSS navigation module

For the positioning and navigation of the robot the dual-frequency GNSS-receiver Topcon HiPer Pro[1] was used together with an external modem to receive correction data via NTRIP. The network RTK measurements are performed using the SAPOS-HEPS service, which the "regional authorities for geoinformation and rural development Niedersachsen[2]" kindly provided. The implementation of the navigation module was done with the Robot Operating System (ROS) [4]. It is an Open Source framework for robotics and offers many different packages. Figure 2 illustrates the simplified architecture of the BoniRob GNSS navigation module. The ROS packages sbpl and sbpl_lattice_planner of the "Search-based Planning Laboratory[3]" are used for path planning. In order for being able to operate with the lattice based planner a set of motion primitives needs to be defined. These motion primitives are assembled by the planner resulting in the path of the robot from a start to goal position. The working area, in which the robot is allowed to navigate autonomously, can be defined with a georeferenced black-and-white image.

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[1] http://www.topcon-positioning.eu/

[2] Landesamt für Geoinformation und Landentwicklung Niedersachsen, Landesvermessung und Geobasisinformation, Podbielskistraße 331, 30659 Hannover

[3] http://www.sbpl.net/Software

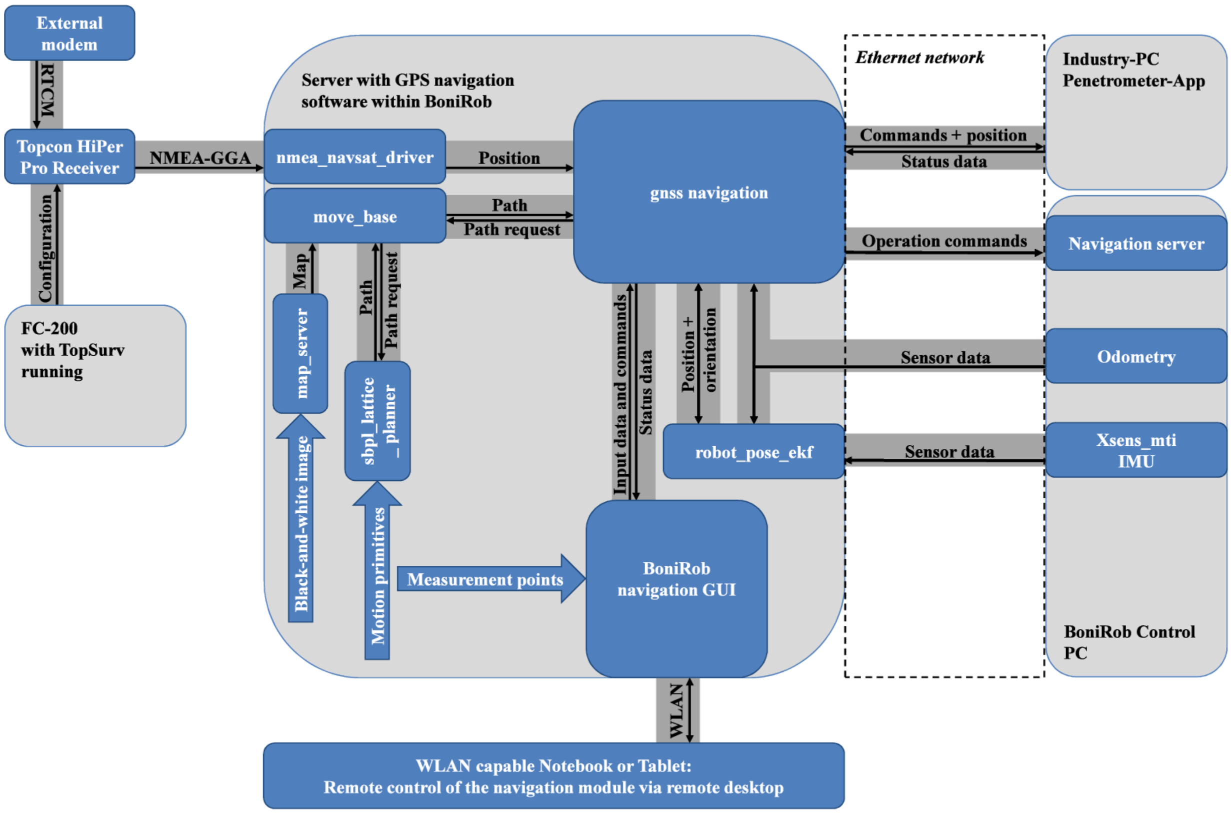


Fig. 1: Overview of the BoniRob GNSS navigation module

Figure 1 gives an overview of the GNSS-based navigation module of BoniRob. The Field Controller Software TopSurv – running on the field computer FC-200 – is used for configuring the Receiver for SAPOS-HEPS Service usage.

Fig. 2: BoniRob during field trials on a meadow of the trial farm of the University of Applied Sciences Osnabrück

Figure 2 shows the measurement system – BoniRob and Penetrometer-App – used in 2014. The Topcon HiPer Pro Receiver and external modem are mounted on the frame of the Penetrometer-App, with the probing rod approximately 0.2 meters behind. One industrial PC is deployed for GNSS-based navigation, the second one for the control of BoniRob. In order for controlling the measurement process via remote desktop a Notebook was used.

Planning of field trials

The measurement process can be planned using GIS tools to define the working space and desired measurement points. For this work the open source software OpenJUMP[4] was used. Figure 4 (b) shows the working area (white) and borders of it (black), as well as two measurement point grids. The grid width of M1 is 10 and of M2 5 meter.

(a) (b)

Fig. 3: Measurement preparation. Orthophoto (a) and orthophoto, definition of the working area and measurement points (b) for the field trials on June 25th 2014

3. Results and discussion

Figure 4 illustrates the performance of the GNSS-based navigation module of BoniRob in the automatized stop-and-go mode from measurement point to measurement point, with an approach accuracy better than 25 cm. Figure 5 (a) shows the corresponding approach accuracy frequency distribution. The Kriging Software VESPER [5] had been used to

[4] http://www.openjump.org/

interpolate the mean of the measured penetration resistance values for a certain depth interval. Figure 5 (b) shows the classified Kriging results applying OpenJUMP.

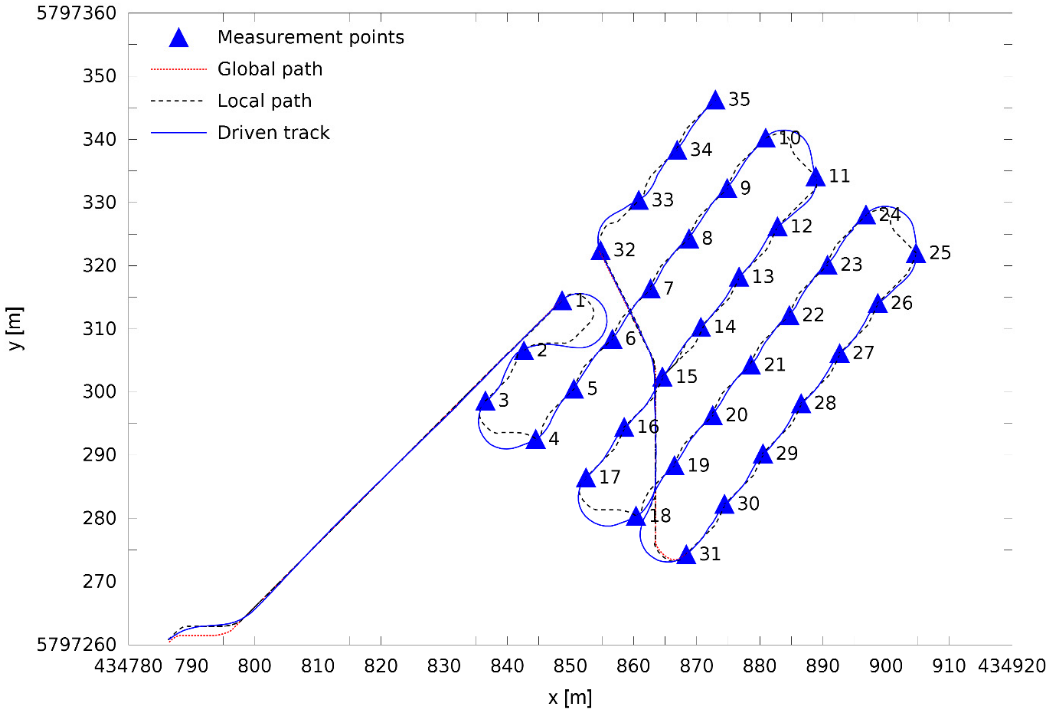
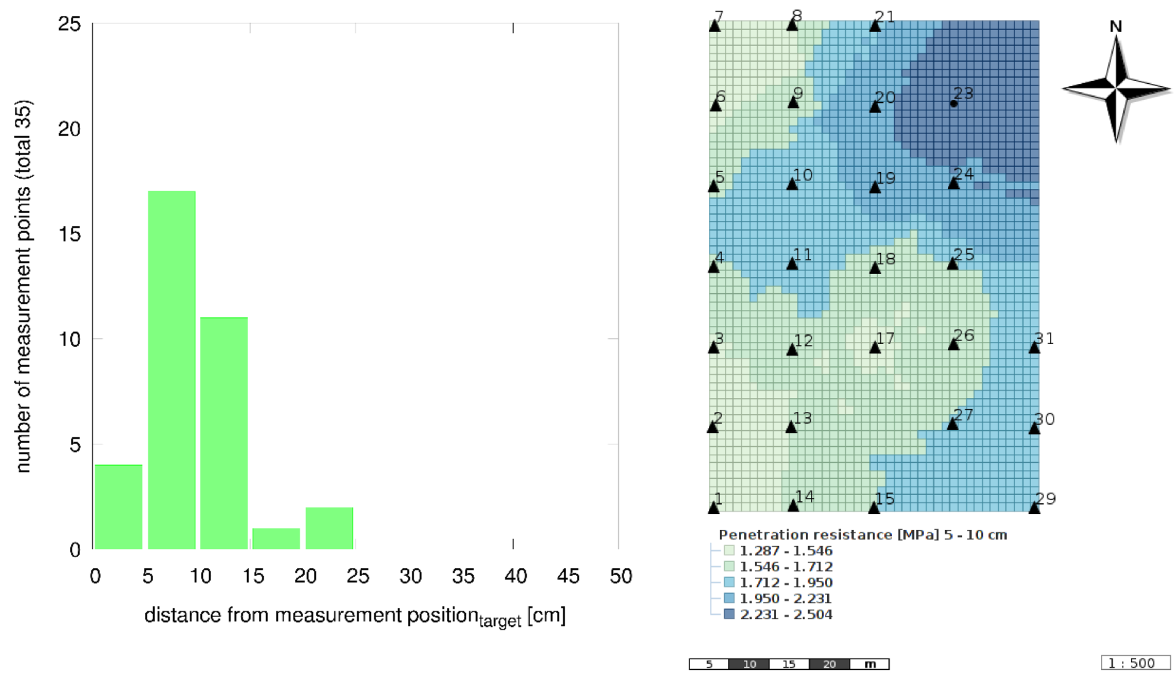


Fig. 4: Measurement points, planned paths and driven track from the field trial M1 on June 25th 2014, represented in UTM coordinates.



(a) (b)

Fig. 5: Approach accuracy frequency distribution of the measurement points 20140625_M1 (a) and Classified Kriging results for the depth interval 5-10 cm of the measurement 20140612_M1 (b)

During the field trial 20140625_M1 the threshold of the penetration resistance measurements was exceeded frequently, which is why almost no data could be collected. Therefore, the results of the field trial 20140612_M1 are shown in Figure 5 (b). The dot symbol of the measurement point 23 denotes that the penetration resistance measurement was stopped within the depth interval 5 to 10 cm. The derived data can be used for soil compaction interpretations. Georeferenced soil property information are the basis for sub-area specific tillage, e.g. by adjusting the working depth considering soil compaction [6]. Furthermore, data of repeatable and automatized soil property measurements are very important for scientific research, e.g. regarding the impact of agricultural land use on the soil.

5. Acknowledgements

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6. References

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