Localisation and navigation of a robot platform using laser scanner and Adaptive Monte Carlo Localisation (AMCL) for an indoor horticultural application

Evaluation of the positioning accuracy of a robot platform in an indoor test environment

Georg Supper [1], Christian Aschauer[1], Andreas Gronauer[1] and Norbert Barta[1]

Abstract: Automation and robotics in horticulture have the potential to replace manual work in repetitive activities, thereby achieving economic advantages. Reliable, sensor-based localisation and navigation in indoor environments would allow easy integration of robotic solutions into existing installations. The aim of this article is to evaluate this localisation accuracy of a robot developed for indoor applications in horticulture. For this purpose, 10 target positions are approached with a robot platform in a test environment and the robot end position and orientation are recorded by a motion capture system (MCS). The result shows that the target positions were reached with an average distance of 45.1 mm and an average angular deviation of 0.4°.

Keywords: Robotics, ROS, automation, horticulture, digitalisation

1 Introduction

In a survey conducted in the mid-1970s, horticulturalists attributed about 25 % of the production costs of plants to labour [AB92]. Ne91 estimated the contribution of labour to total production costs at 34.81 %, including 5.58 % depreciation and 2.50 % interest. Labour is also considered a key factor in the development and maintenance of the greenhouse sector. In the South of Spain, the labour costs for greenhouse production of tomatoes, lettuce, pepper, melon, watermelon, pumpkin, cucumber and bean account for 36 to 40 % of total costs. [Mo13] Automation and robotics in horticulture has the potential to replace manual work in repetitive activities. This results in economic advantages by saving on labour costs. [AFH19]

Many robots designed for outdoor applications use global navigation satellite systems (GNSS) for outdoor localisation. Examples are the field robots BoniRob [Gö14] and

[1] University of Natural Resources and Life Sciences Vienna, Institute of Agricultural Engineering, Peter-Jordan-Straße 82, 1190 Vienna, georg.supper@boku.ac.at https://orcid.org/0000-0002-3405-3384, christian.aschauer@boku.ac.at, andreas.gronauer@boku.ac.at, norbert.barta@boku.ac.at

Ladybird [Un15]. Each driving unit has two mechanically decoupled axes, to rotate the wheel orientation and to drive.

For indoor applications of robots in the horticultural sector, the carrier vehicle's navigation is infrastructure-based, using linear guidance between plants to achieve the positions for various activities with a robot arm, such as harvesting tomatoes in [Qi14]. In the industrial sector, there are commercial solutions such as the logistics robot omniRob-System (KUKA AG, Augsburg, Germany), which already realises navigation with a laser scanner and a simultaneous localisation and mapping (SLAM) algorithm. The omnidirectional drive is equipped with Mecanum wheels. [Rö12]

In order to fully automate horticulture using robotics, it is necessary to ensure reliable localisation and navigation when used in an indoor environment, in addition to the actual main task performed by a robot. An indoor navigation without artificial marks allows more flexibility and the degree of autonomy of a robot is rising. [Ro16] The aim of this article is to explore the potential using a laser scanner for localisation in the indoor horticultural sector. For that, an in-house developed robot with a simple differential drive is evaluated according to its position accuracy at 10 target positions in an indoor testbench.

2 Materials and methods

2.1 Robot

The robot platform consists of a welded steel construction and is driven by 2 electric motors and steered by a differential drive system (see Fig. 1 left). As manipulator for working tools the robot arm UR10 (Universal Robots, Denmark) is used on the robot platform with a reach of 1300 mm. For indoor localisation, a 3D laser scanner (LIDAR) VLP16 (Velodyne, San Jose, USA), an ”inertial measurement unit” (IMU) of type IMU Brick 2.0 (TinkerForge, Schloß Holte-Stukenbrock, Germany) and incremental encoders of type RVP510 (ifm electronic, Essen, Germany) on the drive axes are used. The software concept includes the robot operating system (ROS) with its programs AMCL and navigationstack [SAB19].

In comparison to other localization approaches, AMCL provides a global robot localization, is easy to implement and has less computational demand, but a very small sample has a detrimental effect on position estimation. [Fo99]

2.2 Experimental setup

The indoor test was carried out in the garage of the “Maschinenprüfstation” of the experimental farm in Groß Enzersdorf. For this purpose, a delimited test room with 10 target positions was created. Each of the 10 target positions was approached by the robot

10 times from the same starting area (see Fig. 1 right). The target positions are approached from the right edge of the map. A map of the test environment was generated using the ROS package ”gmapping”.

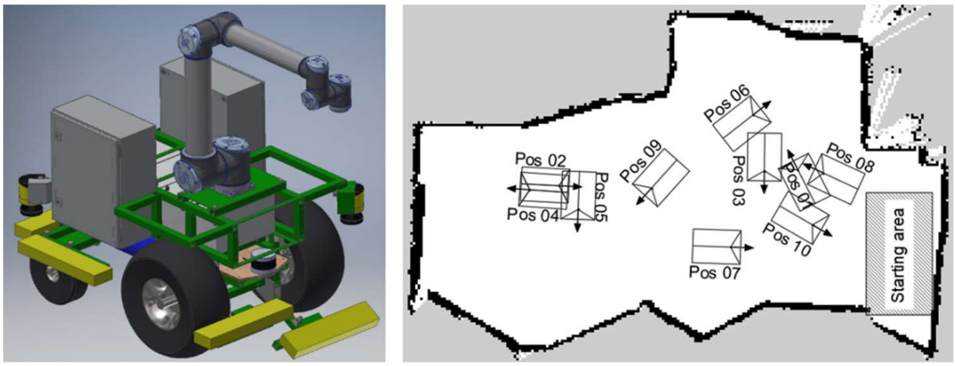

Fig. 1: 3D model of the mobile robot platform (left) and map of the test environment with start area, 10 target positions and orientations (right)

2.3 Measuring systems and evaluation

Eight Vantage V5 (Vicon Motion Systems Ltd, Oxford, UK) cameras were used as MCS in combination with the Vicon Tracker software to determine the robot position in the test room (see Fig. 2). They detect reflector balls which were glued to the robot platform. The robot position is tracked by the software both locally and in its orientation. The statistical evaluation was done with MatLab (MathWorks, Natick, USA).

Fig. 2: Vicon Vantage V5 (left), test environment and measurement system (right)

3 Results and discussion

The positioning and orientation of the robot in front of a working position should be such that it can be processed by the robot arm. Due to the mounting position, work tasks can be performed with the arm within a radius of 1000 mm. In order not to exceed 10 % of the effective reach of the robot arm, the robot must reach the working position with an accuracy of +/- 50 mm. To avoid collision of the robot with a work platform, the deviation from its target orientation must not exceed +/- 5°.

Fig. 3 shows the amount of the distance between the robot end positions and the respective target point as a box plot. The requirement of +/- 50 mm positioning accuracy around a target point is not fully achieved at any position. In position 01, more than 75 % of the values are within this requirement. In positions 03-05 and 07-09, 50 % of the values are within 50 mm around the target point. In positions 02, 06 and 10, the medians are above the limit value. In position 02, the largest deviation of approx. 230 mm can be seen. This position also shows the greatest dispersion. Considered over all test runs, more than 50 % of the values are within the 50 mm. The 75 % quantile is above this with a distance of approx. 70 mm.

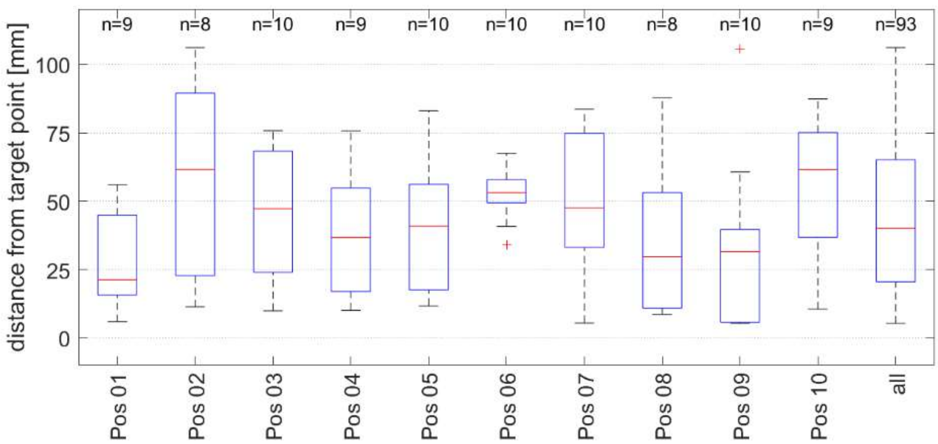

Fig. 3: Amount of the distance of the robot end position to the target points

The results in Figure 4 show that the requirement of +/- 5 ° is met except for position 02 and 08. In position 08, an outlier increases the difference of the orientation to the target orientation. In position 02, the box plot shows that the orientation has a large dispersion of approx. 34°. In order to reach position 02, the robot platform performs a 180° rotation at the target point, which the algorithm does not perform adequately. This behaviour of the robot in position 02 is shown by the increased deviations in positioning and orientation compared to the other positions.

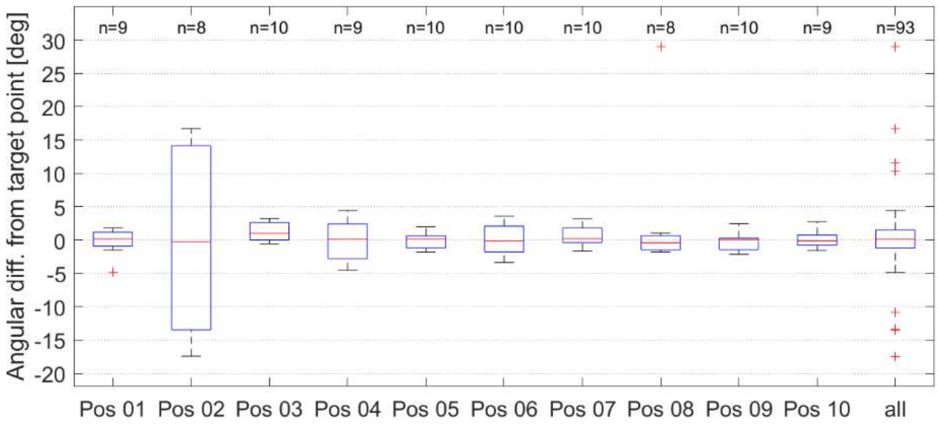

Fig. 4: Difference to the target orientation of the respective target point and all measurements. n<10 caused by triggering the safety module

In comparison with the test results in [Rö12], the mean distance over all positions at 45.1 mm in this work is higher by a factor of 9 and the mean orientation error at 0.4° by a factor of 2.5. The omnidirectional drive with Mecanum wheels plays an important role here in comparison with pneumatic wheels with a differential drive since this enables fine positioning without kinematic constraints.

For practical use at working positions of the robot platform with a robot arm in an indoor application, these results mean that less precise positioning than required is possible. This means that a reduction in the usable reach of the robot arm must be accepted.

4 Conclusion and Outlook

The positioning test in Groß Enzersdorf is a first approach with a simple robot platform based on a differential drive in an indoor environment. The tests show that the requirements for positioning and orientation accuracy can only be partially achieved. If all test runs are considered, more than 50 % of the values are within the 50 mm. The 75 % quantile is above this with a distance of about 70 mm. The 5° requirement of the orientation accuracy is achieved up to position 02.

In practical use of the robot platform, this means to make curtailment in the usable range of the robot arm, to use an additional system for fine positioning, or to extend the algorithms for path planning when approaching the positions by the kinematic constraints.

Further research is necessary to determine the agricultural and economic parameters of the robot platform in a practical usage.

5 Acknowledgement

This work was funded by the Vienna Science and Technology Fund (WWTF) within the University Infrastructure Program.

References

[AFH19] Adegbola, Y. U.; Fisher, P. R.; Hodges, A. W.: Economic evaluation of transplant robots for plant cuttings. Scientia Horticulturae, 246, 237-243, 2019.

[AB92] Aldrich, R. A.; Bartok, J. W.: Greenhouse Engineering, The Northeast Regional Agricultural Engineering Service, 1992.

[Fo99] Fox, D.; Burgard, W.; Dellaert, F.; Thrun, S.: Monte carlo localization: Efficient position estimation for mobile robots. AAAI/IAAI, 1999(343-349), 2-2, 1999.

[Gö14] Göttinger, M.; Scholz, C.; Moeller, K.; Ruckelshausen, A.; Strothmann, W.; Hinck, S.; Grzonka, S.: GNSS-based navigation for the multipurpose field robot platform BoniRob to measure soil properties, 2014.

[Mo13] Montoya-García, M. E.; Callejón-Ferre, A. J.; Pérez-Alonso, J.; Sanchez-Hermosilla, J.: Assessment of psychosocial risks faced by workers in Almería-type greenhouses, using the Mini Psychosocial Factor method. Applied Ergonomics, 44(2), 303-311, 2013.

[Ne91] Nelson, P. V.: Greenhouse operation and management (No. Ed. 4). Prentice Hall, 1991.

[Ro16] Robotics, S. P. A. R. C.: Robotics 2020 multi-annual roadmap for robotics in Europe. SPARC Robotics, EU-Robotics AISBL, The Hauge, The Netherlands, accessed Feb, 5, 2018, 2016.

[Rö12] Röwekämper, J., Sprunk, C., Tipaldi, G. D., Stachniss, C., Pfaff, P., Burgard, W.: On the position accuracy of mobile robot localization based on particle filters combined with scan matching. In 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 3158-3164), IEEE, 2012.

[SAB19] Supper, G., Aschauer, C., Barta, N.: Robotik, ROS, Automatisierung, Landwirtschaft, Digitalisierung. 39. GIL-Jahrestagung, Digitalisierung für landwirtschaftliche Betriebe in kleinstrukturierten Regionen-ein Widerspruch in sich?, 2019.

[Un15] Underwood, J. P., Calleija, M., Taylor, Z., Hung, C., Nieto, J., Fitch, R., Sukkarieh, S.: Real-time target detection and steerable spray for vegetable crops. In Proceedings of the International Conference on Robotics and Automation: Robotics in Agriculture Workshop, Seattle, WA, USA (pp. 26-30), 2015.

[Qi14] Qingchun, F., Wei, C., Jianjun, Z., Xiu, W.: Design of structured-light vision system for tomato harvesting robot. International Journal of Agricultural and Biological Engineering, 7(2), 19-26, 2014.