Crop Row Detection in Maize for Developing Navigation Algorithms Under Changing Plant Growth Stages

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Abstract To develop robust algorithms for agricultural navigation, different growth stages of the plants have to be considered. For fast validation and repeatable testing of algorithms, a dataset was recorded by a 4 wheeled robot, equipped with a frame of different sensors and was guided through maize rows. The robot position was simultaneously tracked by a total station, to get precise reference of the sensor data. The plant position and parameters were measured for comparing the sensor values. A horizontal laser scanner and corresponding total station data was recorded for 7 times over a period of 6 weeks. It was used to check the performance of a common RANSAC row algorithm. Results showed the best heading detection at a mean growth height of 0.268 m.

Keywords Ground-truth · Reference · Algorithms · RANSAC · Total station · LIDAR · Plant position · Growth status · Row navigation

1 Introduction

Autonomous robots can have a key role in increasing sustainability and resource efficiency in food production for future world population [1]. Therefore the
navigation must be planned precisely and be robust enough to deal with the changing conditions on a field. But this requires, that the machines know where the crop plants are and that they don’t get destroyed by the vehicle. As most of the current crops are planted in row structures, detecting these rows is one of the basic needs for the autonomous navigation of robots in semi-structured agricultural environments. Many researches had been conducted on detecting this line structures by camera images ([2],[3]), light detection and ranging (LIDAR) laser scanner data ([4],[5],[6]), or other types of sensors. Nevertheless, precise line detection, relying on noisy sensor data, is still a challenging task for a computer algorithm due to the inherent uncertainty in the environment [6]. Humans can detect objects and shapes because of experience rather than a formal mathematical definition, like a computer algorithm does [7]. The environment has a countless number of variables influencing the sensors, making it hard to get the right information out of the values [8]. Aside from that, plants on the field are changing their shape rapidly, making object recognition even more challenging. First the plants are growing and, second, the conditions are changing. Therefore, there is a necessity for calibration of the algorithms before the robot is able to perform the task autonomously [6].

Also, weather and lighting conditions can already produce big changes in the results. This is especially problematic for image analysis, where alternate and discontinuous luminance usual affects the outcome [7].

To deal with these uncertainties, researchers have used simulated datasets [9], artificial plants ([9], [10]) or recorded datasets ([1],[3],[6]) to evaluate their algorithms. Since a simulation is always an approximate model of the environment, it will never cover all possibilities [8]. When recording data, the question is of how to refer to the algorithm performance. One option is to set the crop row manually [6]. The precise sensor value recording of the same plants over different growth stages, can be a good way for the later evaluation of navigation algorithms. In order to understand how algorithms behave under changing conditions in a field, it is necessary to know the pictured objects and how the sensors react on them. Therefore, it is important to know the correct plant position and parameters. In order to achieve that, the plant parameters must be mapped and referenced in every new test.

The aim of this paper is to show how algorithm analyzing could be improved using precise referenced sensor data, especially when the same plants can be investigated with the same sensors over different growth stages. For that purpose, the data set of a horizontal LIDAR is used. With the help of a highly accurate total station, all sensor data sets can be converted into the same reference frame, in order to obtain comparable results. This approach is tested by the performance evaluation of a common random sample consensus (RANSAC) line fitting algorithm [11]. The RANSAC algorithm has the advantage of being fast and robust against outliers, resulting in advanced performance when dealing with noisy sensor data. Therefore the performance at different growth stages can be precisely evaluated, by using the same reference.