Evaluation of 3D-Sensorsystems for service robotics in orcharding and viticulture

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Abstract

Efficient sensor systems are a prerequisite for robust automation in agriculture. Particularly in the field of autonomous guidance, the demand for reliable sensor systems is significant. A large variety of 3D systems such as laser scanners and ToF cameras are becoming increasingly popular in this field. In the project elWObot (funded by the federal ministry of food and agriculture), autonomous guidance and leaf wall detection are essential tasks. Therefore, various 3D sensor systems are evaluated to test their reliability and robustness in the field. Currently in use are the Sick LMS 511 2D laser scanner with a rotation mechanism, the Nippon Signal FX-8 3D laser scanner, and the Mesa Imaging SwissRanger 4500 3D ToF camera.

1. Introduction

The autonomous guidance of a machine in field conditions is still a challenge due to many environmental influences on the applied sensor systems. To minimize the risks of damage to the machine as well as to human and the environment a highly robust sensor systems is essential. In the project elWObot, which is funded by the federal ministry of food and agriculture, an autonomous service robot for orcharding and viticulture is being developed. It is designed as a diesel-electric vehicle with dimensions (l x w x h) of 2.6m x 1.3m x 0.9m and a payload of about 1.5t. The device will be applied in various tasks such as plant protection, mulching or box transport. A robust machine guidance is an essential requirement in order to handle these tasks but the detection of the leaf wall is also of interest, e.g. for selective spraying [1]. In autonomous navigation, obstacle detection and collision avoidance are critical points [2]. Therefore, autonomous field robots use several sensors for environmental analysis. This study focuses on laser scanners [4] and 3D time of flight cameras [5]. Although 3D sensor systems seem well-suited for applications in viticulture and orchard environments, they still require evaluation. Therefore, three different 3D sensor systems were evaluated for their capabilities in indoor and outdoor environments.

2. Materials and Methods

In this test, the Nippon Signal FX-8 3D laser scanner, the Mesa Imaging SwissRanger 4500 3D time if flight camera and the SICK LMS511 Pro 2D laser scanner combined with a rotation unit were used. The main technical details are depicted in table 1.

The Nippon FX-8 and SwissRanger 4500 were mounted on a mobile sensor platform called Volksbot RT4 developed by the Fraunhofer-Gesellschaft, which is used as a smaller simulation platform for elWObot. The SICK LMS511 with rotation unit is used as a separate unit in these tests because this system is used on loan and could not be attached to the simulation platform. Figure 1 shows the different sensor setups. Within the outdoor environment the mobile platform is placed on a carrier vehicle to better adjust the measurement conditions to the elWObot platform in terms of sensor distance to ground and a smoother movement due to bigger wheels.

Table 1: Technical details of the three different sensor systems

Sensor System	Range	Frame Rate	Resolution	Field of view	Costs
Nippon Signal FX8	0.3-15m	10 fps	65h x 40v	60°h x 50°v	ca. 4200 €
Mesa Imaging SR4500	0-9m	10-30 fps	176h x 144v	69°h x 56°v	ca. 4350 €
SICK LMS 511 Pro + Rot. Unit	0-80m	1 fps	0.5° x 3.6°	190°h x 190°v	ca. 20000 €

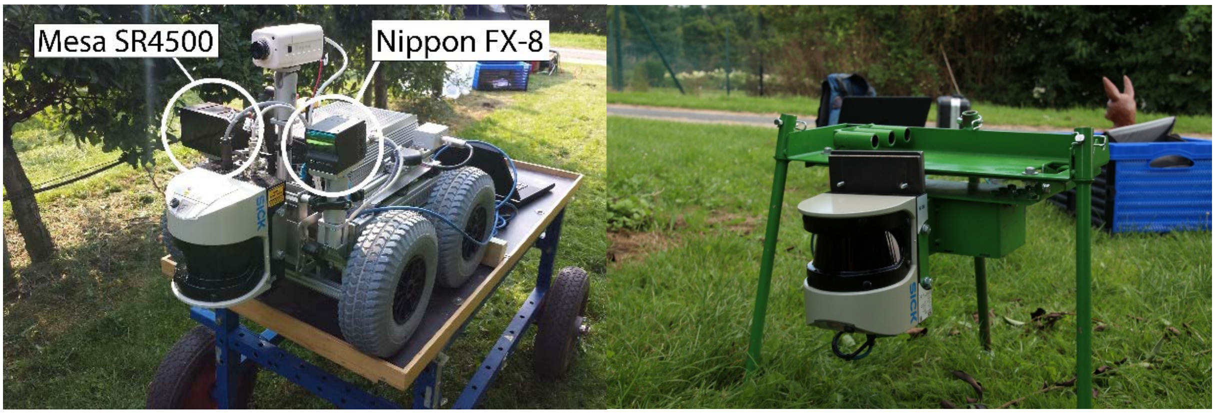

Figure 1: Sensor setups – Mobile platform with SwissRanger 4500 and Nippon FX-8 (left) SICK LMS511 Pro with rotation unit (right)

The sensor tests were performed in two different environments. First, an indoor environment was used with three rows of artificial vines as shown in figure 2 on the left. This was done to test the general quality of the sensor data. Each row consists of 10 plants with 252 leaves on each plant. The rows were 1.4m wide by 5m long and approx. 1m high. The stem of the plants were made of wood with a height of about 30cm. Further measurements were taken in the outdoor orchards of the University of Applied Sciences in Osnabrück at “Williams Crist pear” rows shown in figure 2 on the right. The trees were approx. 12 years old and cut as a hedge with a width of approx. 40-60cm. The height was approx. 3m and the rows were approx. 3.5m wide. The orchards were mulched before the measurements in order to create an even ground. The conditions for the sensor systems are comparable in vineyards and orchards although row distances and heights could vary. Thereby the results are mutually transferable to either environment.

Figure 2: Measurement environments – indoor vineyard (left) and outdoor orchards (right)

In order to validate the ability of the named sensors for object recognition within the row, different objects were used as obstacles. For indoor tests, a cardboard box (40cm x 24cm x 15.5cm) was used as well as a fawn model made of plastic with a height of 33cm. In outdoor measurements the box and the fawn were also used, as well as a black toolbox and a human approx. 1.8m tall. The obstacles were placed at various positions within the rows.
During the measurements the objects were placed in-between the rows and the mobile platform with the Nippon FX-8 and SwissRanger 4500 was moved through the rows. Moreover, the angles of the sensors relative to the tree-rows were varied between 0° and 40° in 10° increments. With the SICK LMS511 only static measurements were taken at different positions with different obstacles. A variation of the viewing angle in the rows was not necessary for testing due to the 190° field of view of the sensor system.
For data acquisition, a ROS (Robot Operating System) [6] based system is used. The three sensor systems publish 2.5D point-clouds of the resulting data where each point in the clouds consists of a three component vector with its origin at the sensors center. To analyze these point clouds, the Point Cloud Library [7] is used where several filters and algorithms are already implemented to handle multidimensional data. For environment recognition, the

point-clouds are separated into different segments. Before segmentation, the input point-cloud is filtered to remove statistical outliers and, therefore, reduce noise. After that the segmentation is performed using the RANSAC-algorithm to find planes in the point-cloud in order to detect the ground as well as the leaf walls of the tree rows. These segments are extracted into new separate point-clouds. Thereby the left and right tree row are distinguished. The residue of the input point-cloud is filtered again with a radial outlier removal filter to remove artifacts and highlight the obstacles in the rows.

3. Results

For all datasets of the indoor tests, a robust detection of the ground level, leaf walls and obstacles was possible. Figure 3 shows point-clouds of the three systems with frontal alignment as well as a reference picture. The SwissRanger was influenced by low noise, which was possible to eliminate, while no noise was detected in the datasets of the laser scanners.

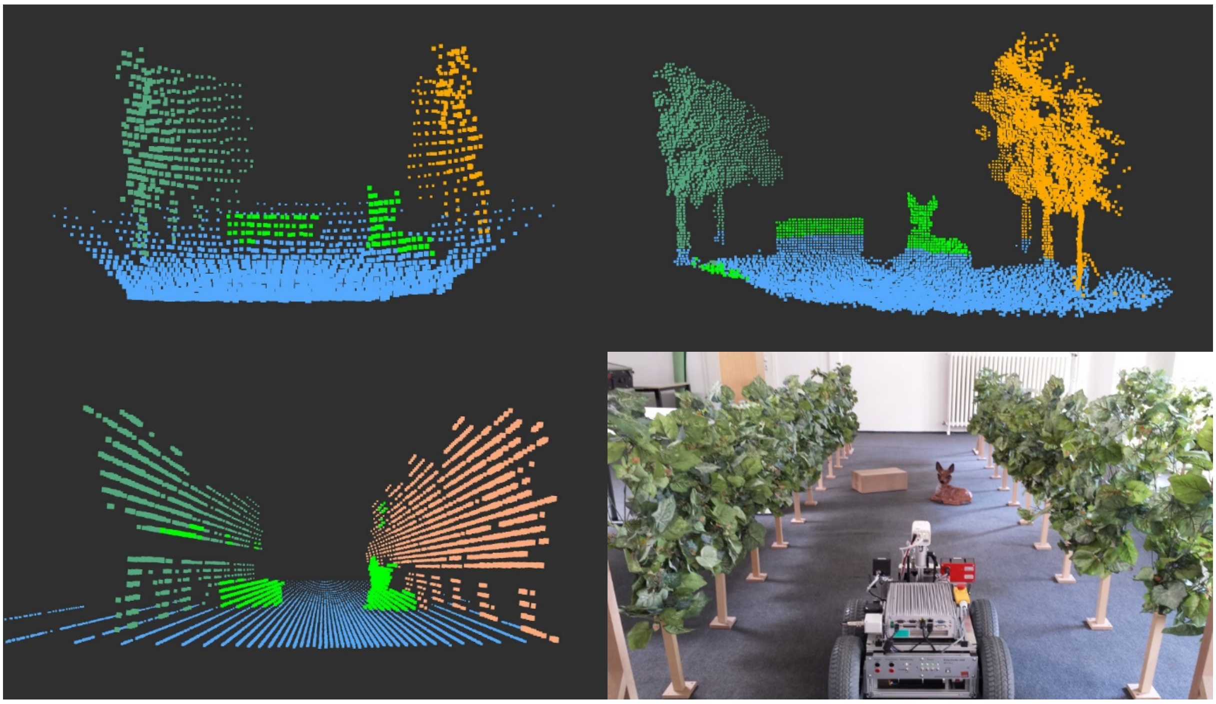

Figure 3: Nippon FX-8 dyn. indoor result (upper left); SwissRanger 4500 dyn. indoor result (upper right); LMS511 indoor result (lower left); reference image (lower right)

In the outdoor tests shown in figure 4, the laser scanners still provide robust data for ground, leaf wall and obstacle detection. The data of the SwissRanger is relatively noisy within dynamic measurements and objects with low reflection, e.g. the toolbox which could not be detected. Since the tree rows were detected, navigating in the row may be possible. However, additional sensors may be necessary in order to accomplish a robust obstacle detection algorithm for safety objectives.

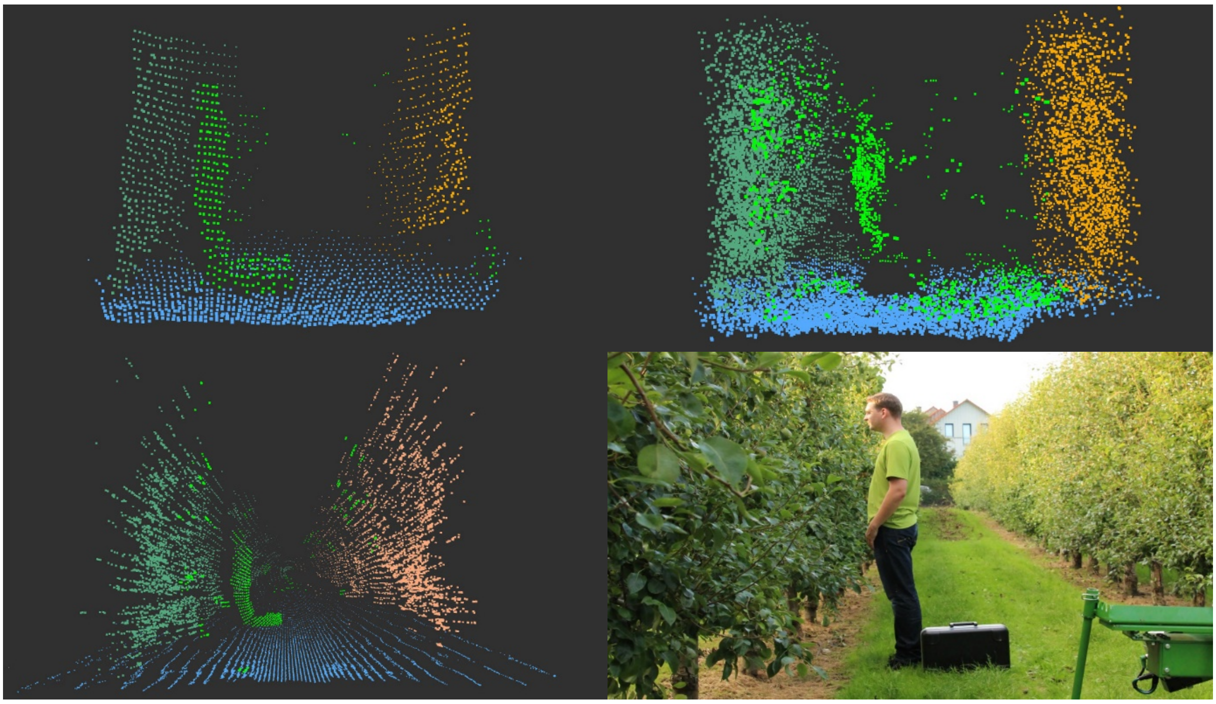

Figure 4: Nippon FX-8 dyn. outdoor result (upper left); SwissRanger 4500 dyn. outdoor result (upper right); LMS511 outdoor result (lower left); reference image (lower right)

In general, the SwissRanger was determined to have the highest resolution in this test while the laser scanners performed with a higher detection range and acquired more robust datasets. The large field of view and range of the LMS 511 Pro is particularly suitable for early obstacle detection and navigation purposes. The detection of gaps in leaf walls remains challenge due to limited resolution of the systems and shading of branches.

4. Conclusion

Both laser scanner systems are well suited for navigation purposes in orchards and vineyards due to their robust data acquisition with minimal noise. The large range and field of view of the LMS 511 Pro is advantageous, but the FX-8 is less expensive and likewise suitable for this application. The SwissRanger 4500 seems to be well suited for indoor environments and produced relatively detailed point-clouds. The sensor has issues with noise caused by ambient light in outdoor environments which necessitates substantial post processing and could lead to issues with false detection in real-time applications. An issue such as this would be unacceptable with respect to safety. Therefore, the SwissRanger 4500 cannot be recommended for obstacle detection and navigation in outdoor environments.

5. Acknowledgements

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