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Automotive Radar Sensor for Object Detection in the Agricultural Environment

An automotive parking assistance system was tested for its suitability in obstacle detection in the agricultural environment. The chosen medium range radar sensor can detect both organic material and machinery. Under the given conditions the accuracy of the distance measurement is below ± 15cm, sufficient for obstacle detection. Correlating the target detection with real objects was unsatisfactory in the beginning, because the radar sensor detected more objects than there were really present. Through post-processing the correlation between measurements and real objects could be improved.

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Keywords

Radar, object detection, driver assistance system

Literature

[1] s.m.s. smart microwave sensors GmbH: Full Documentation Universal Medium Range Radar "UMRR", 2005
[2] *N.N.*: Lasermesssysteme LMS 2xx. Technische Beschreibung, SICK AG, Division Auto Ident Düsseldorf, 2003

The application of steering aids relieves the driver of agricultural machines from the driving task. This leaves more time to focus on the process control of the working task of the machine. On the other side this implies that the application of a steering aid reduces the attentiveness of the driver on the drive path. In order to keep up a safe machine operation an additional supervision of the environment becomes necessary.

As the object detection plays also a major role in automotive driver assistance systems, a radar sensor from an automotive parking assistance system was chosen. The main goal was to ascertain the accuracy and the reliability of the radar sensor under agricultural environmental conditions. To determine the potential of the automotive radar sensor for an application as a safety feature on agricultural machinery.

The Radar Sensor

The „Universal Medium Range Radar Sensor" (UMRR) has been developed for an automotive parking assistant. It is a Puls-Doppler Radar intended for the measurement of dynamic objects. The sensor is capable of detecting up to 30 objects at a time. The signal frequency is 24 GHz. The measurement range lasts from 1 m to 20 m. The sensor output is the power density of the reflected signal, the polar coordinates and the radial velocity, as well as the number of detected objects. The radar beam propagation is nearly two dimensional. The opening angle in the elevation is ~ 45° while in the azimuth it is less than 10°. The peripheral zone of the radar beam is not clearly delimited [1].

Test Set Up

The test set up I (*Fig. 1*) has been utilised to verify the accuracy of the distance measurement as well as the reliability of the object detection of the radar sensor. For this purpose static and dynamic measurements with one object and with multiple objects have been executed.

The test object was a metal tube of 1.5 m length and a diameter of Ø 0,35 m which was standing upright. For the static tests the object was positioned at different surveyed spots throughout the range of the radar beam (*Fig. 1*). During the dynamic measurements the object has been pulled through the effective range of the radar beam from the left to the right hand side. The single object test was executed at an open space without any obstructions. Whereas the test object has been positioned in front of a solid wall for the multiple objects test (*Fig. 1*). Vehicle based test were carried out to verify the vehicle de-

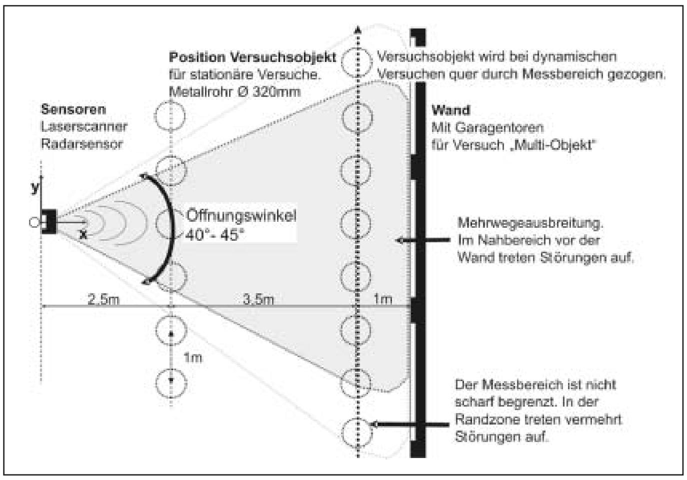

Fig.1: Test set-up I, basic tests, object detection

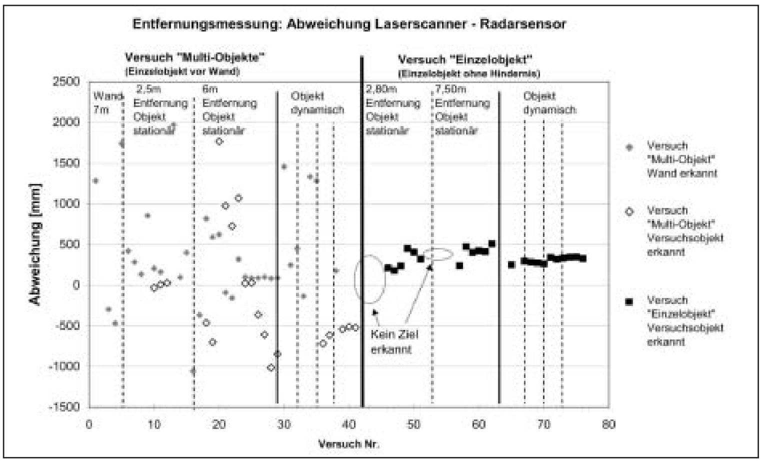

Fig. 2: Results of the distance measurements, deviation between Laser reference data and radar sensor readings

tection abilities of the sensor. Additionally the power density of the reflection on organic material has been inspected.

The distance measurements were referenced by a laser scanner „Sick LMS 291-S05“, this having an accuracy of ± 35 mm [2].

Results

The test results show that the chosen radar sensor is capable of detecting moving objects in the agricultural environment without problems. Dirt and dust particles donít influence the measurements significantly.

As the sensor has been developed for dynamic measurements it shows some problems with the reliability while stationary. Caused by sensor-immanent signal interferences, non existing, virtual objects are being detected. Due to the sensor set up and the pulse radar principle these interferences can only be suppressed successfully while the objects are moving.

The power density of the signal reflection depends on the material as well as on the distance, the impact angle of the signal, the geometric dimensions and the surface structure of the object. In the agricultural application the distance of the object and the impact angle of the signal vary constantly. Therefore the power density of the reflected signal on object detection varies vastly. The accuracy of the distance measurement is not affected by the material.

Distance Measurement

The single object test shows that the radar sensor is capable of detecting strong reflecting objects with a good accuracy. The deviation between the distance measurement with the radar sensor and the reference measurement with the laser scanner is depicted in *Figure 2*. The standard deviation (Std.) of all measurements of the single object test is ± 90 mm (Fig. 2, right hand side). Considering only the dynamic measurements the standard deviation improves to ± 35 mm, whereas the measurements of only the static tests show a standard deviation of ± 110 mm. This underlines the positive influence of the object movement on the measurement results.

The left hand side of *Figure 2* illustrates the results of the multiple objects test. Comparing the left hand side (multiple object test) of Figure 2 with it’s right hand side (single object test) it becomes obvious that the measuring result in the multiple object test are influenced strongly by multipath effects between the different objects. The standard deviation of all results in the multiple objects test is ± 700 mm. In this case the result can not be improved by a dynamic object.

Object Detection

The radar sensor is capable of vehicle detection without any problems. The accuracy of the distance measurement between two vehicles is ± 0.14 m (Std.).

During the multiple objects test the test object has not always been reliably detected in front of the wall. This means that a smaller and weaker reflector might be shaded by the reflection of a strong reflecting object.

Another problem lies in the correlation of measurements and real existing objects. The difficulty is to differentiate between false reflections of unknown origin and true reflections of real objects. Over all the sensor finds to many virtual or false objects caused by interferences or multipath. In the multiple objects test (test object in front of the wall) only 10 % of the measurements showed the exact number of existing objects. In 90 % of the test runs the radar sensor detected too many (false) targets.

In order to improve the correlation between detected and existing objects a software script to classify and filter the data has been developed. Datasets with low mean values of the power density of the signal reflection and with high standard deviation on the distance measurement have been identified as interference. With the post processing of the data, the correlation of the object detection could be improved significantly to 70 % (*Fig. 3*).

Resumee

Radar sensors and the related data analysis tools are developed for each specific application. This is why they are highly customised systems. The adaptation of an automotive radar sensor to the agricultural environment implies a reduction of the accuracy and more than that a loss of reliability. In order to successfully apply automotive radar sensors in the agricultural environment the data analysis has to be adapted. The filtering methods, which have been developed in this project, have shown significant improvements of the results. Considering a future safety system a further enhanced data analysis is needed.

Fig. 3: Object detection, correlation of measurements with real objects; comparison of raw data vs. results from post processing