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DGPS-supported safety system for farm machinery

Automatic guidance control for farm machines and tractors should support the driver both physically and psychologically during monotonous steering work, and simultaneously allow better exploitation of machine capacity as well as higher work quality. Despite this, it is not possible to exclude the risks of interference or breakdowns of the sensor technology, gaps in the guidelines, obstacles on the field such as ditches and electricity pylons as well as concentration lapses on the part of the operator. The integration of suitable GPS equipment can increase the functional safety of guidance control in the interests if man and machine.

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With the advanced development of various data correction services, and the improved precision of DGPS technology for the location and navigation of vehicles associated with these, the functionality of automatic steering systems developed by research and industry for farm machinery and tractors is also being extended within the area of tasks where safety is of relevance and is available at economically-justifiable terms for manufacturers and operators.

Ground module of the safety system

With financial support through the German Research Society (DFB) solutions for a safety system for tractors have been developed in the last years at the Institute for Agricultural Engineering and Land Culture. The main task areas are the timely recognition of field borders and obstacles.[5] The safety system is constructed in a modular form comprising, alongside automatic steering with various sensor systems [6] from a GPS/DGPS receiver, an on-board computer with instrumentation and operating facilities, a GIS extended with special program parts [7], a radar sensor for ground coverage, and a gyroscope for the determination of the angle speeds of the vehicle.

The finding of the tractor's actual position is through algorithms which process the position data from the GPS/DGPS receivers along with the values from the radar sensor and gyroscope and compare them with the predetermined safety-relevant co-ordinates in the GIS [8]. The result is a calculation giving the distances to obstacles or field borders. A minimum distance can be pre-selected by the user at the terminal, under which the safety system would be activated. Below, more details are given as to the functioning of the individual program parts for position and distance determination.

Determination of position on the field

First, gyroscope zero point is calibrated with the vehicle stationary. With the giving of the first DGPS measured position, one also received the first shared point from the level of gyroscope/radar and DGPS. This is the starting point for the calculated course-line of the gyroscope/radar level. As long as the tractor is stationary the following DGPS measurements are used for the improvement of starting position accuracy through averaging calculations.

With the beginning of the tractor journey the determination of direction is possible. Depending on the precision of the DGPS position data, the information from the gyroscope/radar joint level follows after 5 to 10 m with sufficient agreement to the receivable DGPS values.

Further necessary algorithms are the continuous position and direction corrections on this level. These are the result of the possible drift of the gyroscope calibration curve zero point, calibration and systemic errors of the radar sensor, and errors in the distance calculations.

In order to be able to deliver the running position and direction corrections on gyros-

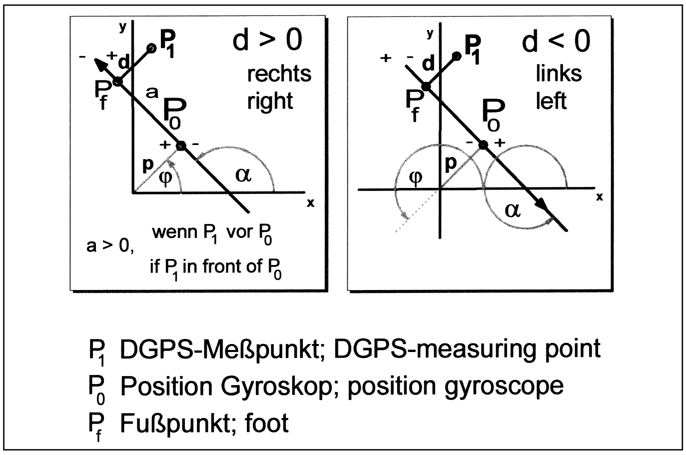


Fig. 1: Geometric pattern for adapting the levels gyroscope/radar and DGPS

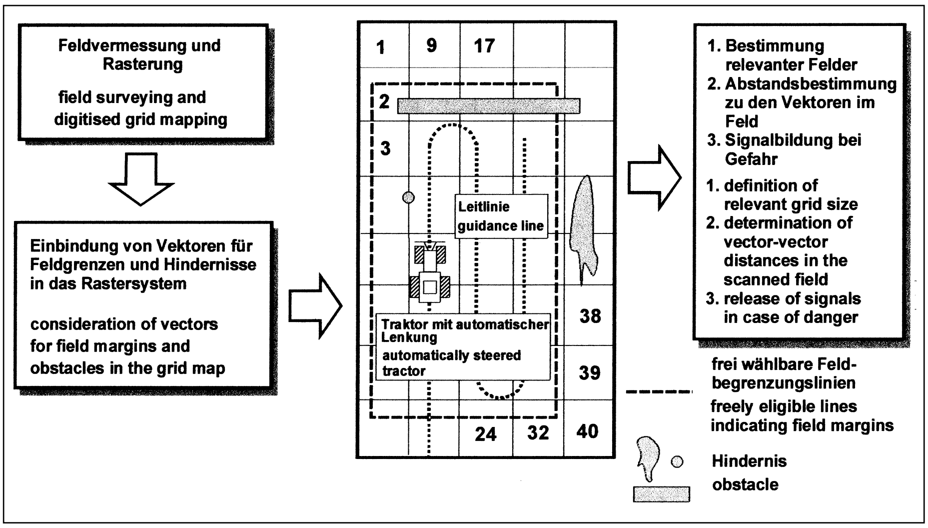
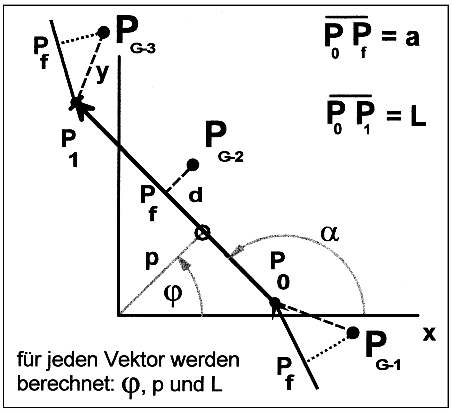


Fig. 2: Scheme of the data processing in the safety system Automatc Guidance Control



BFig. 3: Geometric pattern for determining the distance to obstacles and field boundaries

cope/radar level to the DGPS measurement points, the distance of several DGPS measurement points from the calculated course-line must be analysed. This can take place with the help of the'Hessian Normal Form' because this allows a direction determination from 0∞ to 360∞, and a regression without supply of an axis.

$$x \cdot \cos\varphi + y \cdot \sin\varphi - p = 0 \qquad (1)$$

The separation distance d and the position of a point relative to the direction of travel is able to be very easily determined with

$$d = x_1 \cdot \cos\varphi + y_1 \cdot \sin\varphi - p \qquad (2)$$

Thereby would be determined the separation distance d of the DGPS measuring point P1 vertical to the calculated course-line of the position gyroscope P0 in dependence of the chosen direction of travel: if the point Pf therefore lies left from P1, d is < 0, if it lies right d is > 0.

The separation distance a is the separation distance of the footpoint (Pf) from d to position P0. It is also possible to determine a with the'Hessian Normal Form'. The distance a>0 occurs when P1 lies before P0 in the travel direction, and vice versa *(fig. 1)*.

Calculation of separation distances to obstacles and field borders

Within the additional module'Grid Oriented Area Administration', developed together with the Saxony software house and GIS marketers AGROCAD, Kleinbardau, the following program parts (in order of printing) are to be developed (fig. 2).

- Determining of relevant grids with obstacles or field border vectors in direction of travel
- Determining separation distances for these vectors
- Signal development in the case of danger , i.e., by encroaching into a predetermined (pre-selected) safety distance

For the calculation of separation distance between tractor and obstacles, etc., the consecutively numbered fields of the grid – as shown in *fig. 2* – right and left alongside the actual field, and the fields in the direction of travel before the tractor position and right and left from this, are drawn-in. For these fields it is then checked whether they contain vectors for field borders or obstacles. Entered in the vector data as point data in the co-ordinating system are the vectors for the field border and the obstacles.

For every vector is calculated the variables (and p of the'Hessian Normal Form' as well as the separation distance L between the points *(fig. 3)*.

Thereby it is checked whether the footpoint Pf of the position plot for the actual DGPS position (in fig. 3 the points PG-1 to PG-3) is to be found before the starting point, between starting point and end point, or behind the end point of the vector. Onto this is calculated the separation distance a of the footpoint Pf from starting point of the vector P0.

If the value is negative, Pf lies before P0 and the separation distance to P0 must be calculated as the least distance from vector.

If positive, and a is (L, Pf is positioned between starting and end point. No further calculations as to the vector are necessary, d is the separation distance to the vector.

If a>L, then the separation distance to P1 must be calculated as the shortest distance to the vector.

Application example

In *fig. 4* the positions calculated by the already described program parts of the levels gyroscope/radar and DGPS in comparison to the real driving line during the journey over the field by an automatically steered tractor, are demonstrated. The maximum deviations from the real position are smaller than 5 m and therefore satisfy the safety relevant demands.

Where the tractor draws nearer than 10m to a purely virtual obstacle in this case (black areas), the safety system should react. Where the guide lines are continuously followed, the steering takes place through the sensors of the applied automatic system. The position determination through GPS/DGPS receiver and gyroscope/radar investigates parallel to this relevant safety fields and their separation distance from the actual tractor position. If these lie under the predetermined safety distances, an alarm is sounded.

Conclusion

According to the given targets for a safety system warning when a predetermined safety distance to obstacles and field borders is exceeded, it is possible to achieve results which satisfy demands in practical fieldwork, even with lower-cost-range sensors and GPS technologies.

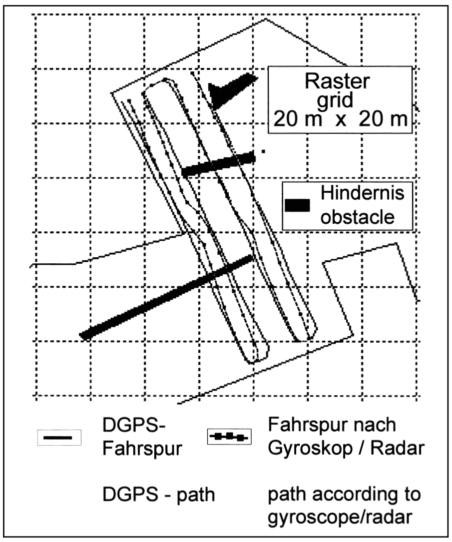


Fig. 4: Field experiment with levels for coupling DGPS and gyroscope/radar