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Automatic coupling between tractor and implement

The coupling process between tractor and implement is complicated and time-consuming. The tractor must drive up to the implement exactly within a range of centimetres, which requires great precision and lots of driver experience. Bad weather, darkness, or counterlight can additionally compound the working conditions during the coupling process. Every year, numerous persons are severely injured during tractor-implement coupling. In order to avoid such accidents and to reduce the driver's workload, an automatic tractor-implement coupling system was developed at the Chair of Agricultural Machinery of the Technical University of Dresden, which is going to be discussed in this contribution.

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The present study was supported by the German Research Council.

Keywords

Tractor, implement, automatic coupling, occupational safety

The tractor hitch had already been developed in the nineteen twenties. Even though the primary objective of this invention was constant tractive power transmission [1], this development also opened up the possibility to lift and carry implements. However, the coupling and uncoupling of implements is difficult and time-consuming because the upper link and the hydraulic rams often need to be adjusted manually in order to change the kinematics of the hitch. Especially in recent years, the tractor hitch has been upgraded due to the demand for greater operating comfort and shorter set-up times. Here, in particular the equipment of the hitch with a hydraulic upper link, hydraulic rams, and hydraulic lateral stabilizers must be mentioned [2]. This facilitated the coupling and uncoupling of implements significantly, in particular when a frame coupler was used. However, precise driving-up to the implement is still necessary. For this reason, a novel tractor hitch with six degrees of freedom - the hexapod hitch - was developed at the Chair of Agricultural Machinery of the Technical University of Dresden in cooperation with John Deere in Mannheim (*Fig. 1*) [3].

The coupling process with the hexapod hitch

The application of the hexapod hitch allows the frame coupler to be moved in space along a given motion path. If the position and orientation of the implement in relation to the tractor are known, they can be used as set values for the control of the hexapod hitch, and the implement can be coupled fully automatically. The coupling process can thus proceed as follows:

When the tractor approaches the implement, its position and orientation are determined by appropriate sensor systems. If the implement is within the motion space of the hexapod hitch, the driver is informed by the tractor electronics. He can then stop the tractor and start the coupling process by pressing a button. Hence, the implement can be coupled swiftly by means of automatic hexapod hitch control along a stored motion path. This leads to considerable time savings because the coupling process no longer depends on the skills of the driver and the ambient conditions.

Techniques for the measurement of the position and orientation of the implement

For the development of an automatic implement coupling system suitable for practical application, the sensor systems for the measurement of the position and orientation of the implements must in particular meet the following requirements:

- A measuring range of up to 3 m and a maximum angle of ± 45° at the horizontal level
- Low costs
- No moving parts
- The implement elements should not require any adjustment, maintenance, or energy supply
- No restriction of the functionality of the implements
- Robust against the influences of rain, snow, counterlight, and vibrations

First, several different measuring techniques will be examined with regard to these requirements.

Among other purposes, the global positioning system (GPS) is used for the localization of vehicles and the automatic guidance of agricultural machinery along the calculated line. The combination of the two-frequency GPS receiver with the correction data of a fixed reference station (DGPS technique) allows the positions to be measured in the centimetre range at up to 20 Hz [4].

The determination of the spatial position of the implement in relation to the tractor requires three two-frequency DGPS receivers each on the tractor and the implement. For cost reasons, this makes GPS systems unsuitable for automatic coupling.

Laser scanners working according to the principle of pulse travel time are often used for vehicle guidance along existing lines (e.g. automatic combine guidance along the grain edge [5]). The adjustment of the lenses in the scanner results in a deflection of the pulsed laser beam. Thus, the environment is scanned at one level. Due to the high travel speed of light (~ 300,000 km/s), this measuring techniques requires higher resolution for travel time measurement. For this reason and due to the sophisticated optoelectronic and mechanical systems, it is very expensive. The moving parts required for lens adjustment are another disadvantage of such measuring systems.

The travel-time technique based on ultrasonic sensors seems to be significantly more promising. Due to the low price as compared with other sensors [6], ultrasonic sensors are often used for the detection of guidelines for automatic steering, which have been created by agricultural cultivation. The guidance of self-propelled harvesting machines or tractors along swath-, plough furrow-, and crop stand edges are examples of such applications [7]. Dust, light reflections, humidity, and vibrations, which occur in practical use, only exert a small influence on the measurement results of the ultrasonic sensors and do not cause any problems.

Given these conditions, the travel-time technique based on ultrasonic sensors was chosen for the determination of the position and orientation of the implement. At the Chair of Agricultural Machinery of the Technical University of Dresden, a mobile test stand was erected wìth three ultrasonic transmitters and one radio receiver installed on the implement and three ultrasonic receivers and one radio transmitter placed on the tractor. Every 300 ms, a control implement on the tractor sends a radio command to the ultrasonic sensors to transmit alternating short 40 kHz switch signals. In this case, the distance of the individual transmitter to the three receivers equals the product of travel time and the speed of sound in air, which is 343 m/s at 20 °C [8]. Based on these distances, the position of each transmitter and, hence, also the position and the orientation of the implement in relation to the tractor are determined.

Conclusions

The use of ultrasonic sensors enables the position and the orientation of the implement in relation to the tractor to be established. This allows the implement to be coupled fully automatically with the aid of the hexapod hitch. The development of this principle provided a cost-effective solution which enables occupational safety and work quality during the coupling process between tractor and implement to be improved considerably. The disadvantage of this solution is that the ultrasonic sensors on the implement need to be supplied with energy. For this reason, techniques of image analysis, which currently are still expensive even though they are being used more and more often in robot- and tool technology, are intended to be examined in future studies.

Literature

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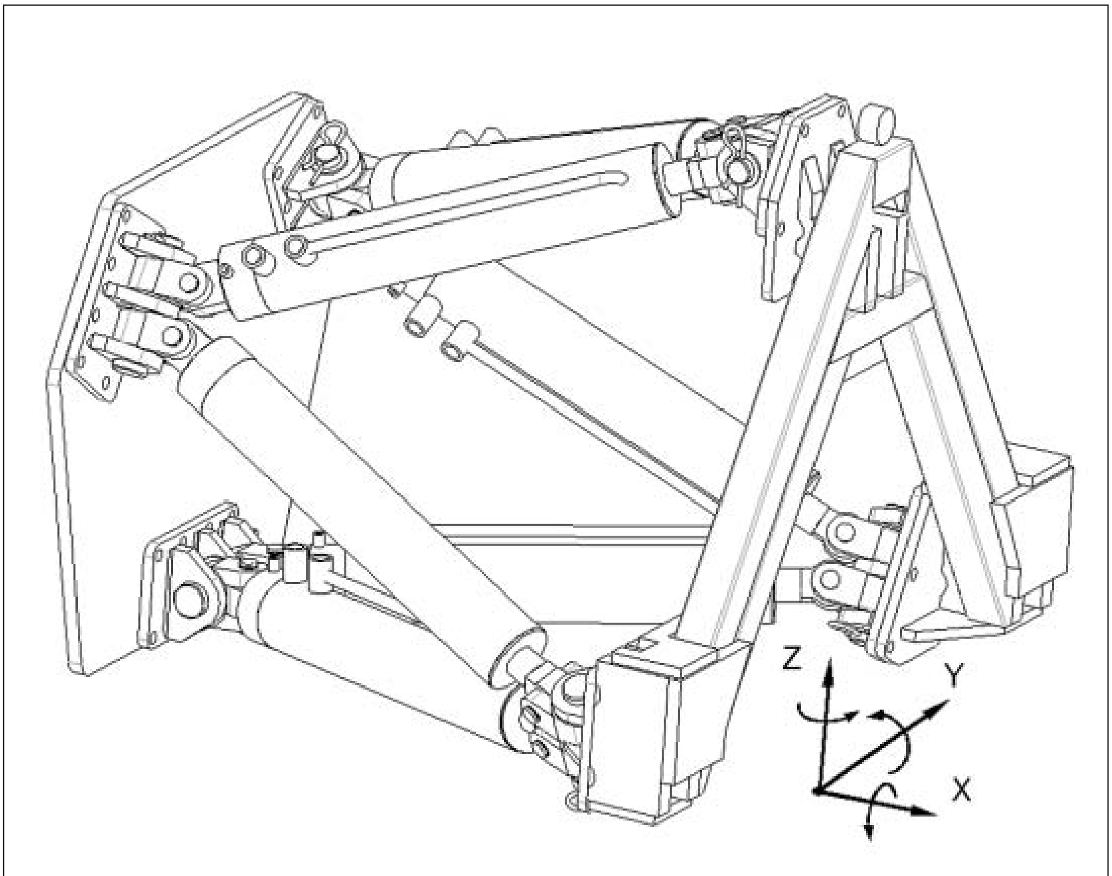

Bild 1: Hexapodanbau

Fig. 1: Hexapod hitch