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Automatic steering systems used in viticultural tractors

Automatic steering systems are basic elements in the context of precision farming technology. In the sector of viticulture, so far only few knowledge is given. An empirical study on the expedience of an exemplary selected, ultrasonic-based steering system is carried out to prove the functionality of automatic steering systems in viticultural tractors. General suitability is determined by ergonomic and economic criteria regarding the handling of the tractor. Rendition of the test results leads to the conclusion, that prospectively increasing proliferation of automatic steering systems in viticulture is to be expected.

Keywords

Viticulture, ultrasonic, steering, precision farming

Abstract

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Established manufacturing processes in viticultural production require a high intensity of mechanization with up to 20 tractor passages per row and year. To ensure a most widely mechanization of cultivation works, a linear arrangement of vines in trellises is necessary. A precise steering along these structures requires a high potential of attention by the driver of the tractor or self-propelled working machine. In the consequence, this attention is no longer available for controlling the plant population or working quality of attached working machines.

Automatic steering systems are able to relieve the tractor driver significantly. They also effect an obvious increase of working quality and efficiency of utilization of tractor and attached machinery [1]. Those insights, made in classic agriculture, can be transferred to viticulture in an analogous manner. In viticulture, as a specialized crop, attention should be laid to the fact that less an accurate steering parallel to the previous track is important, than rather a precise guidance along the vineyard trellises. Considering this aspect, satellite-based steering systems are only suitable to a limited extent for a use in viticulture [2]. In this specific case, a direct sensing of plant structure, respectively trellis structure should be preferred. The degree of driver's relief caused by using an automatic steering system is non-accessible by direct scientific measurement of physical or psychic parameters. Instead, indirect measuring methods have to be favoured [3].

A subsequent presented field-study tries to show potential effects of relief by measuring the driver's heart rate and it's

variability as a suitable indicator. In this case the circumstance has to be considered, that heart rate as an indicator for physical and psychic stress is influenced by a multifactorial conglomerate of technical and sociological factors.

Suitability of automatic steering systems in viticulture

Within in quoted field-study an automatic steering system, type „Ultra Guidance PSR Sonic“, made by Reichhardt Elektronik was used (**figure 1**). The sensing technology of this steering system is assembled of four independent ultrasonic sensors, which could be installed adjustable on top of the tractor's engine-covering hood. For carrying out the study a tractor type Fendt, 209V was used. The used tractor basically matches standard equipment (**figure 2**).

Several measurement drives were performed to evaluate the reliable function of the tested steering system under different operating conditions (**figure 3a-c**). To verify potential effects of the automatic steering system on the respective driver's condition, selected rows were passed both with automatic or manual steering and with varying drivers. During the test drives, the indicator heart rate was steadily measured and recorded.

To check user's acceptance and demand for automatic steering systems, a quantitative survey was carried out. Target group for this survey were visitors of agricultural exhibitions.

Driver's relief and increase of productivity

By reference to the carried out test drives in different vineyards and with varying test drivers, the reliability of the checked steering system can be certainly confirmed.

Canopy sensing was confidently realized by the used system and it's related ultrasonic sensors. A precise steering between the rows is ensured under varying canopy conditions in summer during strong vegetation (**figure 3a**) and also in winter with only rudimentary branches (**figure 3c**).



Customer terminal Reichhardt Ultra Guidance PSR steering system

System failures or disturbances were not observed during regarded test period. Evaluation of the test driver's subjective feelings leads to the conclusion, that quality of steering is higher in automatic variety than in manual one, on condition that accurate sensor and software configurations are set.

Analysis of the recorded heart rate of one exemplary chosen driver shows a sufficient sensitivity of the selected test method (figure 4). The graphical illustration shows an obvious parallelism of heart rate trend between manual and automatic steering variety. Turns, which have to be performed manually at the end of the row result in significant and periodic increases of the measured indicator (peaks t_1 to t_7). Beyond that, repeatable effects of heart rate increase could be verified, caused by an



Experimental tractor with mounted ultrasonic sensors

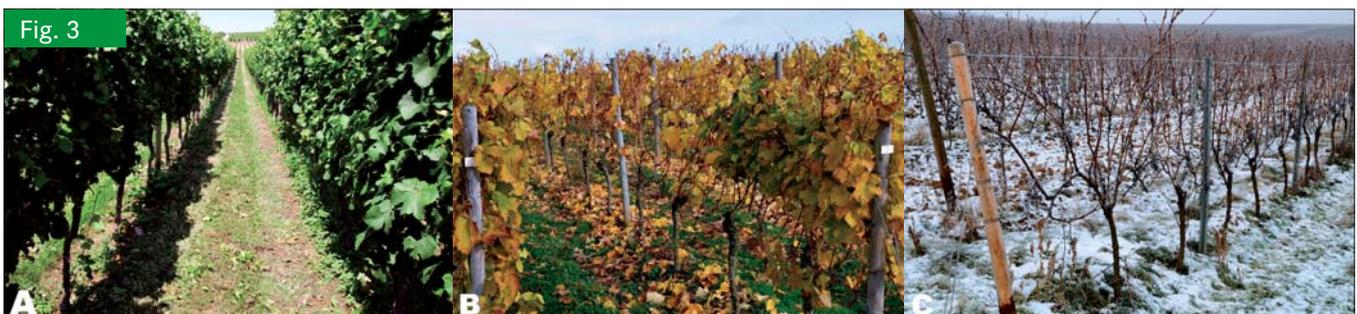
obstacle centred in the regarded row. This obstacle required a manual intervention by the driver (peaks o_1 to o_4).

The mean of the driver's heart rate was about 77,0 heartbeats \cdot min⁻¹ in automatic steering variety and about 78,2 heartbeats \cdot min⁻¹ in manual one. Heart rate in manual variety therefore was lightly increased versus automatic variety. By reference to the depicted test results, currently no significant driver's relief can be proofed. Nevertheless, corresponding tendencies become obvious.

An interpretation of these results is determined by the fact, that all test drives were performed with a single tractor without any attached working machines. Therefore, a higher level of attention to the basic working process was not required. Perhaps a reliable proof of relief by the chosen indicator urgently needs a higher level of concentration and stress, altogether.

Evaluation of the quantitative survey leads to the conclusion, that there are coherences between size of cultivated farmland and the individual demand on automatic steering systems. Table 1 shows, classified by size of cultivated farmland, an individually higher rated usefulness of steering systems with increasing size of winery.

A similar coherence exists both with the participant's motivation for buying an automatic steering system and with their



Functional check of the steering system under varying conditions of canopies

individual willingness to pay. Increasing the size of cultivated vineyard leads also to a significantly higher willingness to make use of other precision farming techniques and general receptiveness to technical innovation.

Conclusions

Basic suitability of ultrasonic based guidance systems for use in viticultural tractors could be confirmed. The expected relief with regard to the tractor driver can not be proofed sustainable in due consideration of the current data. Although, especially by regarding the results of the carried out survey, this effect becomes obvious by tendency. To clarify this basic study's interrogation, further ones are essential. They have to regard chosen working steps in vineyard cultivation, particularly combinations of tractors and attached machines. Measurement of individual driver's relief should be repeated under consideration of modified test conditions and critical review of the chosen indicator. Results of the quantitative survey lead to the conclusion, that

practical orientated viticulturists show a basically acceptance and demand on automatic steering systems.

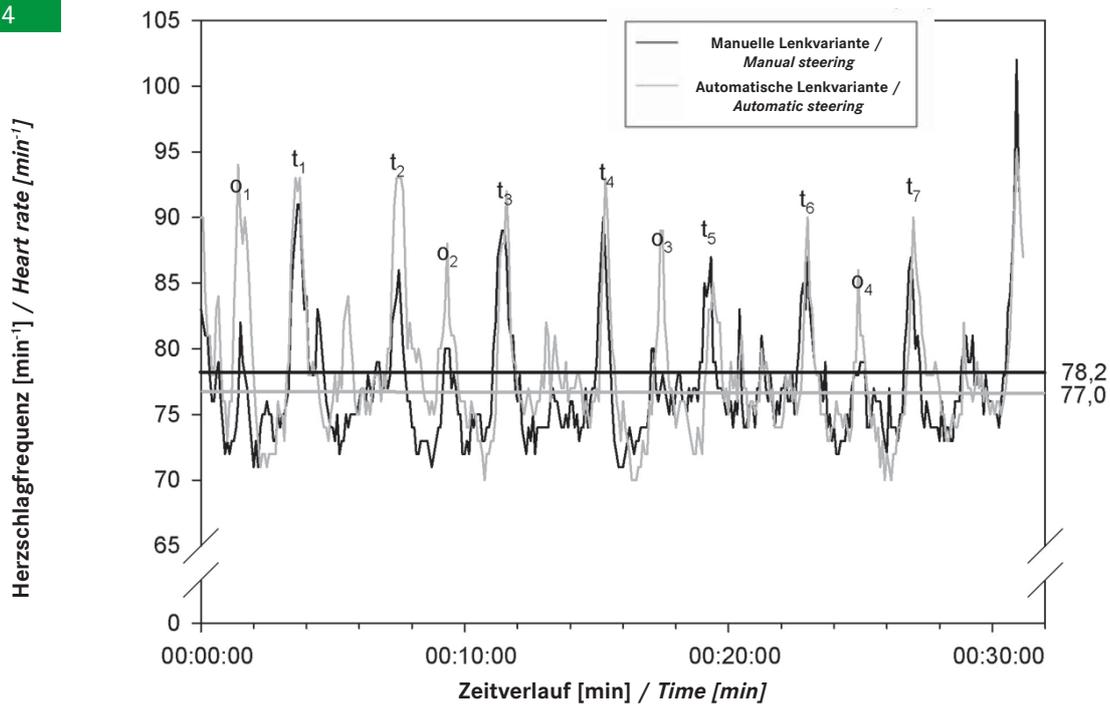
Further use of steering systems seems to be a future trend in regard to the current generation of viticultural tractors. Consistent application of multi-row working machines demands an increased utilization of driver assistance systems. In this context, automatic steering systems are basic elements in a sophisticated chain of control and regulation devices. Altogether, basic aim of technological progress in viticulture, similar to current evolution in classic agriculture, has to be the integrated automation of agricultural production chain. Especially, the most widely mechanization of steep slope viticulture shows manifold capabilities to transfer this technology into practice.

Table 1

Results of the quantitative survey classified by cultivated farmland

Fragestellung/ Question		Betriebsfläche/ Cultivated farmland		<5 ha		5–10 ha		10–15 ha		15–20 ha		>20 ha	
				n = 10		n = 14		n = 13		n = 11		n = 6	
		n	[%]	n	[%]	n	[%]	n	[%]	n	[%]	n	[%]
Altersklasse/ Class of age	< 20	2	20,0	1	7,1	2	15,4	1	9,1	-	-		
	20–40	5	50,0	6	42,9	6	46,2	5	45,5	3	50,0		
	40–60	2	20,0	4	28,6	3	23,1	4	36,4	2	33,3		
	> 60	1	10,0	3	21,4	2	15,4	1	9,1	1	16,7		
Hofnachfolger vorhanden? Farm successor existent?	Ja/Yes	3	30,0	6	42,9	5	38,4	4	36,4	2	33,3		
	Nein/No	4	40,0	3	21,4	3	23,1	2	18,2	1	16,7		
	Selbst Nachfolger/ Successor myself	1	10,0	3	21,4	3	23,1	3	27,3	2	33,3		
	Keine Angabe/No answer	2	20,0	2	14,3	2	15,4	2	18,2	1	16,7		
Nützlichkeit automatischer Lenksysteme im Weinbauschlepper? Usefulness of automatic steering systems in viticultural tractor?	Sehr nützlich/Very useful	2	20,0	4	28,6	3	23,1	4	36,4	3	50,0		
	Nützlich/Useful	3	30,0	4	28,6	6	46,2	3	27,3	2	33,3		
	Weniger nützlich/Less useful	2	20,0	3	21,4	3	23,1	2	18,2	-	-		
	Nicht nützlich/Not useful	1	10,0	2	14,3	-	-	-	-	-	-		
	Keine Angabe/No answer	2	20,0	1	7,1	1	7,7	2	18,2	1	16,7		
Einsatzmöglichkeiten im Weinbau (Mehrfachnennungen)/ Possible uses in viticulture (multiple answers)	Grubber/Cultivator	6	60,0	8	57,1	10	76,9	7	63,7	4	66,7		
	Laubschnitt/Canopy cutting	4	40,0	5	35,8	5	38,5	6	54,5	3	50,0		
	Pflanzenschutz/Plant protection	7	70,0	7	50,0	7	53,9	9	81,9	5	83,3		
	Traubenernte/Harvest	3	30,0	6	42,9	5	38,5	7	63,7	4	66,7		
	Sonstiges/Other	2	20,0	5	35,7	4	30,8	5	45,5	1	16,7		
Anschaffung eines Lenksystems beabsichtigt? Acquisition of steering system planned?	Ja/Yes	4	40,0	5	35,8	5	38,5	5	45,5	3	50,0		
	Nein/No	2	20,0	3	21,4	3	15,4	3	27,3	2	33,3		
	Keine Angabe/No answer	4	40,0	6	42,9	5	38,5	3	27,3	1	16,7		
Zahlungsbereitschaft/ Willingness to pay	<5.000 €	6	60,0	6	42,9	5	38,5	3	27,3	2	33,3		
	5.000–10.000 €	2	20,0	2	14,3	4	30,8	4	36,4	2	33,3		
	10.000–15.000 €	1	10,0	4	28,6	2	15,4	2	18,2	1	16,7		
	> 15.000 €	1	10,0	2	14,3	2	15,4	2	18,2	1	16,7		
Nutzung anderer Precision Farming Technik? Use of other precision farming technology?	Ja/Yes	2	20,0	3	21,4	3	23,1	3	27,3	1	16,7		
	Nein/No	4	40,0	5	35,8	4	30,8	3	27,3	2	33,3		
	Geplant/Planned	2	20,0	3	21,4	3	23,1	4	36,4	2	33,3		
	Keine Angabe/No answer	2	20,0	3	21,4	3	23,1	1	9,1	1	16,7		

Fig. 4



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