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Straight-Line Accuracy of an Autopilot Tractor at Various Speeds: A Preliminary Assessment on Malaysia's Flat Terrain

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Abstract
Nowadays autopilot mode become one of the alternative modes in driving tractor besides manual and unmanned or autonomous. Although the system has been successfully introduced in its country of origin, however, specialized assessments of this system on the areas which are different from its country of origin are prime interest to be investigated whether it suits a local terrain condition of any country. Thus, a preliminary assessment of the straight-line accuracy of autopilot tractor running at various specified levels of speed was conducted in order to understand its suitability with Malaysia's terrain conditions. In this study, a New Holland TD5.75 tractor equipped with Trimble® EZ-Pilot® Steering System and Trimble® FmX® Plus Application was trialed on flat terrains that were overgrown with grasses at the UiTM farm in Jasin, Melaka, Malaysia. Three levels of autopilot tractor forward speeds, i.e. 1000 rpm, 1500 rpm, 2000 rpm were selected as the parameters in measuring straight-line accuracy of the tractor. The SPSS ver. 25 and spreadsheet software were used to analyze the collected data. This study found that there is a significant different between straight-line accuracy of each the tested speeds. It also showed that there is a relationship between the tested speeds and straight-line accuracy.

Keywords: Farm machinery, Autopilot tractor, Auto-guidance, Auto-steering, Mechanization

Introduction

The use of tractor in agriculture operations have been increasing drastically in Malaysia since past decades. This situation can be seen through increasing the import value of tractor for the country since five decades from2,685,000 USD in 1968 to 90,324,000 USD in 2008 (FAOSTAT, 2016). With the broadly usage of tractors in Malaysia today, the machines also contribute in solving the labor shortage in agriculture sector in the country. Besides, tractors also play roles in improving the advancement of mechanization in most of agricultural operations in the country through lightening workload and reducing human energy expenditure in the operations.

In line with the advancement of technology, various driving modes of tractors have been introduced and sold in the market. The autopilot tractors have been widely not only have been used in the country of its origin, but also in several developing countries. Several studies have been revealed in the literatures such as Santos et al. (2018), who reported the position errors in sowing of peanut in curved and rectilinear routes using autopilot tractor in Brazil. Another study reported by Jahns (1997), who introduced a concept which makes use of auto guidance components to minimize the costs of implementation. Easterly et al. (2010) tested the performance of satellite-based tractor auto-guidance using a vision sensor system. Lipinski et al. (2016) compared the tractor implement unit that was operated in conventional method when the tractor was operated manually and autopilot modes, which relied on satellite navigation.

Being a new technology, the performance of autopilot tractor is still unknown in Malaysia. Thus, assessments of this tractor driving mode on its suitability with local terrain conditions is prime interest to be investigated as no one to the best of our knowledge has studied this aspect. This paper is a preliminary attempt to assess the straight-line accuracy of an autopilot tractor at various speeds on Malaysia's flat terrain. Straight-line accuracy of tractor when operating in the field is crucial to be retained in order to minimize overlapping of works width for each trip. Higher overlapping trips could reduce field efficiency of an operation. Three levels of tractor engine speeds i.e. 1000 rpm, 1500 rpm, 2000 rpm were selected as the parameters in measuring straight-line accuracy of the tractor. In this paper, the error of accuracy at each level of speeds were presented. Besides, the relationship between the speeds and the error of accuracy of autopilot were also discussed.

Materials and methods

This preliminary study was carried out at university farm in UiTM Melaka, Jasin campus, Melaka, Malaysia. The selected area has a slope ranging from 0% to 0.5%, and it is considered as flat terrain (Weiss, 2001). During the field observation, the ground surface was overgrown with grasses. The weather was considered as heavy cloudy, thus, it might affect the signal of GPS. A New Holland tractor model TD5.75 at 75 horse power sizes that equipped with autopilot system, consisting of Trimble® EZ-Pilot® Steering System and Trimble® FmX® Plus Application was used as main subject of the study. Details specifications of tractor and autopilot system were shown in Tables 1 and 2. In this study, the tractor was operated on an area of 30 m x 30 m size. Three straight lines ropes were lied down on the ground to be tracked by outer right side of front and rear tires. Outer right side of front and rear tires of tractor was set to overlay the ropes during the test. Any strip along the straight movement of the outer side of tractor tires on the ropes was considered as an error. Thus, the ropes were also as references measurements for detecting the error of straight forward movement of the tractor when moving alongside the straight lines. The levels of tractor speeds were set at three different rates i.e. 1000 rpm, 1500 rpm, and 2000 rpm. The autopilot tractor mode GPS system was activated with five time replications at each of speed. Figure 1 shows the GPS setup for tracking the straight-line routes in the field. The movement of tractor tires then was followed closely a person to observe the error in straight-line accuracy. Any error in straight-line movement was then marked using spray paint. Once completed, the marked paints were perpendicularly measured. They were recorded as error in straight-line accuracy of autopilot. The SPSS ver. 25 and spreadsheet software were used in data analysis.

Table 1. Specifications of New Holland TD5.75Tractor

Engine	*Number of cylinder/aspiration/valve*	*4/TI/2*
	Emission level	*Tier 3*
	Capacity	*3908 cm^3*
	Rated horsepower-ISO TR 14396-ECE R120	*56/75*
	Rated engine speed	*2300 rpm*
	Max. Torque – ISO TR14396	*298@1400*
	Fuel tank capacity	*110 litres*
	Service intervals	*300 hours*
Hydraulic	*Main pump flow*	*36 l/min*
	MegaFlow™ pump flow	*48 l/min*
	Steering and services pump flow (Mechanical shuttle/Hydraulic shuttle)	*29 l/min*
Remote valves	*Type*	*Deluxe*
	Max. no. rear valves	*3*
	Max. no. mid mount valves	*2*
Linkage	*Max. lift capacity at ball end*	*3565kg*
	Max. lift capacity through the range (610 mm behind ball ends)	*2700 kg*

Table 2. Specifications of Autopilot Unit

Brand	*Trimble*	*Trimble® EZ-Pilot® Steering System and Trimble® FmX® Plus Application*
System	*DC power*	*Supplied by TM-200, 27 volts, 3.5 Amps*
	Processor	*1 GHz quad core*
	Storage	*Primary embedded memory – 32GB*
Mechanical	*Dimension*	*312 x 214 x 45 millimetres (plus connectors)*
	Weight	*2.5 kg (5.5lb)*
	Mount	*4 M6 screws on 75 mm centres*
Housing	*Material*	*Magnesium*
	Environmental rating	*IP55*
Connections	*USB (1 side facing, 1 rear facing)*	*USB 2.0*
	Ethernet (Via TM-200)	*RJ45 connector*
	CAN (sources 5VDC)	*RJ11 connector*
	Port Expander (optional)	*1 port for CAN bus, I/O, and serial*
	HDMI output	*DVI connector*
Temperature	*Operation*	*0◦C to 65◦C*
	Storage	*-40◦C to 85◦C*
LCD display	*Size*	*307 mm*
	Touchscreen	*Protective capacitive touch*
	Resolution	*1280 x 800*
	Brightness (adjustable)	*1000 candela/m^3*
Front facing camera	*Type*	*Low light level, colour*
	Resolution	*1.3 Megapixel*

Figure 1. The GPS system of autopilot mode has been setup for tracking the straight-lines routes in the field

Results and discussion

Table 3 shows the errors of autopilot mode during testing. The lowest error in straight-line accuracy of 6.462 cm was found at the highest speeds level of 2000 rpm, while at the highest error of 38.318 cm was recorded at the lowest speed of 1000 rpm (Figure 2). Generally, within the three levels of tested speeds, it is concluded that that the higher speed, the lower error in straight-line accuracy. This agree with Lipinski et al. (2016), who reported the actual operating width of the tractor-implement under three travels speeds i.e. 3 km/hr, 6 km/hr and 12 km/hr. They found out that increasing of the autopilot tractor speed has increased the actual operating width of the tractor-implement, or reduced overlaps of tractor-implement routes in the field. It cannot also be denied that the GPS is not always accurate and can affect the straight-line accuracy of tractor movement in the field. This is consistent with Morgan and Ess (1997), who said that the accuracy of GPS depends on several factors such as satellite clocks, atmospheric conditions, or the GPS receiver quality.

Table 3 Error in Straight-Line Accuracy at Various Speeds of Atutopilot Mode

Speed	Error (cm)					Mean error (cm)
(rpm)	1	2	3	4	5	
1000	21.57	49.02	0	77.25	43.75	38.318
1500	10.13	15.25	25.17	28.6	10.8	17.99
2000	9.14	10.17	2.5	5	5.5	6.462

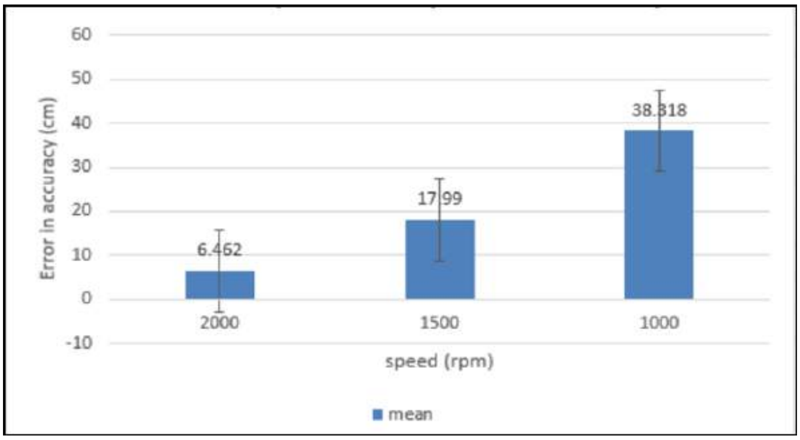

Figure 2. Relationship between speeds and error in straight-line accracy of autopilot in the field.

Conclusions

A preliminary evaluation of straight-line movement of autopilot tractor at various speeds i.e. 1000 rpm, 1500 rpm, and 2000 rpm on Malaysia's flat terrain has been successfully conducted. The findings of this study simply concluded that the level of speed and accuracy have a strong relationship. As it is in a preliminary stage, generally, this study has successfully initiated to discover another factor that may contribute to the error in straight-line accuracy of autopilot tractor, besides the GPS accuracy factors. Overall, the autopilot mode has potential to be used to overcome the problem regarding inadequate workers in Malaysian agriculture sector, and also reduce the time usage and operator fatigue while doing the agricultural activity. Comprehensive and complete study of this driving mode on various terrains conditions in Malaysia was recommended for further studies.

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