The Planter, Kuala Lumpur, 95 (1115): 97-104 (2019)

Preliminary Assessment on the Potential for Use of an Autopilot Tractor on Malaysia's Flat Terrain

MUHAMMAD HAIRIE HAMDAN AND DARIUS EL PEBRIAN*
Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Melaka, 77300 Jasin Campus, Merlimau, Melaka, Malaysia

Currently modern tractor with autopilot steering system has become one of the classy modes in tractor operations system. However, specialised assessment of this system on areas, which are different from its country of origin are of prime interest to be further investigated. Therefore, this preliminary study was conducted to assess the straight-line accuracy of autopilot tractor running at various specified levels of speed on Malaysia's flat terrain conditions. The new tractor[1] equipped with an autopilot mechanism was evaluated on flat terrain that was overgrown with grasses at the UiTM (Universiti Teknologi MARA) farm in Jasin, Melaka, Malaysia. This automation is employed to offer high-accuracy steering for the operator while driving a tractor and improve safety in the field. Three levels of autopilot tractor engine speeds, i.e. 1 000 rpm, 1 500 rpm, 2 000 rpm (equivalent to 3.4, 4.2, 5.5 km per hour speed) were selected as the parameters in assessing straight-line accuracy of the tractor. This study found that there is a significant difference between straight-line accuracy of each of the tested speeds. It also showed that there is a relationship between the tested speeds and straight-line accuracy. Thus it is worthwhile to pursue further evaluation of its usefulness in selected field operations.

Keywords: *Farm machinery, autopilot tractor, auto-guidance, auto-steering, mechanisation.*

Tractor is one of the important power machineries for farming operations that facilitates the farmers worldwide to run daily farm operations. With its specialties, the tractor plays the role as a universal prime mover to run various implements for reducing human drudgery, increasing productivity and improving timeliness of agricultural operations. Tractors are used for pre-harvest operations such as land clearing, ploughing, rotovating, crop up-keeping etc. The tractor can also be used to transport the yield products either in-field or from harvesting platform to the packing house. Assisted by the tractor, the farmers are not only able to cover the large-scale works, but also complete the work within the dates that have been set according to the plan. In other words, the use of a tractor can save time, thus, increasing the productivity per unit farm area as compared with human power or animal-assisted power. In fact, according to Srivastava *et al.* (2006), today's modern tractor is a very sophisticated machine with hydrostatic drive, electrohydraulic servos[2] to control draft force

*email: darius@uitm.edu.my

Note:

1 A 75 HP New Holland TD5.75 equipped with Trimble® EZ-Pilot® Steering System and Trimble® FmX® Plus Application.

2 Servos is an automatic device that employs negative feedback of an error-sensing to rectify the action of mechanism.

and the operating depth, and an ergonomically designed, climate-controlled operator's station.

In Malaysia, the importance of tractors as one of the inputs in agriculture has been drastically increased. This situation can be observed through the increasing import values of tractors into the country in the last five decades, which showed an increase from USD2 685 000 in 1968 to USD90 324 000 in 2008 (FAOSTAT, 2016). The wide usage of tractors in Malaysia today has contributed in addressing the labour shortage in the agriculture sector in the country.

In line with the advancement of global positioning systems (GPS) and geographic information systems (GIS) of today's modern technology, various driving modes of tractors have been introduced in the market. Besides, the manual or conventional driving mode, which depend on the driver manually controlling the steering, the alternative driving modes such as autopilot and unmanned or autonomous mode are also becoming as the classy modes in driving a tractor in an effort of minimising the driver's intervention when driving a tractor.

Among the above-mentioned driving modes, the autopilot mode has been receiving good responses from the farmers since its system is more cost-effective and simpler in design as compared to the unmanned or autonomous modes. Murphy (2009) said that the current autopilot systems help farmers complete field operations faster, more accurately, safely and comfortably, and with less operator fatigue than ever before. With autopilot mode, tractors can work at night or in dusty and low-visibility conditions to avoid losing valuable field time. Autopilot also saves time by allowing operators to drive faster with better precision and no field call-backs.

The autopilot tractor has been widely used and evaluated in several developing countries and thus not only limited to the country of its origin. Numerous studies have been revealed in the literatures such as by Santos *et al.* (2018), who reported the position errors in sowing of peanuts in curved and rectilinear routes using autopilot in Brazil. Another similar study was reported by Jahns (1997). He introduced a concept which makes use of auto guidance components to minimise 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-steering modes, which relied on satellite navigation.

However, for Malaysia, this machine is still new and is in the initial stages of the process of commercialisation. In fact, the performance of autopilot tractor is still unknown in the country as no one to the best of our knowledge has studied this aspect. Thus, assessment of autopilot tractor suitability with Malaysia's local terrain conditions was considered to be of prime interest to be investigated because it is believed the usage of this system would be a great potential to accelerate modernisation of technology in agricultural operations.

This paper reports the results of a preliminary attempt to assess the straight-line accuracy of an autopilot tractor at various speeds: a preliminary assessment was done on Malaysia's flat terrain. The straight-line accuracy of an autopilot tractor is important to be evaluated since as stated by Siemens *et al.* (2008), overlaying or overlapping of work width for each trip cause unused capacity, which lead to reduction of field efficiency of an operation. Three levels of tractor engine speeds i.e. 1 000 rpm, 1 500 rpm, 2 000 rpm (equivalent to 3.4, 4.2, 5.5 km per hour speed) were selected as the parameters in measuring straight-line accuracy of the tractor. The error of accuracy at each level of speeds were evaluated. Besides, the relationship between the speeds and the error of accuracy of autopilot were also evaluated.

METHODOLOGY

This preliminary study was carried out at the university farm in UiTM Melaka, Jasin campus, Melaka, Malaysia. The selected area has a slope ranging from 0 per cent to 0.5 per cent, and it is considered as flat terrain (Weiss, 2001). During the initial 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 tractor at 75 horse power (HP) size that was equipped with an autopilot mechanism, consisting of autopilot steering system along with its guidance and control systems application was used as the main subject of the study. The autopilot steering system is an electric steering motor associated with steering wheel. The guidance and control system is an application that is being used to execute the autopilot system and control the movement of tractor. It has GPS guidance system, controller, modem and data management system installed in a specialised computer display. The display is attached on the tractor cab for the operator to easily run the system. Thus, the entire programme or command for the autopilot system of tractor is set up through this application. Being an assisted steering system, the autopilot steering system offers high-accuracy steering for the operator while driving a tractor. Once it is activated, the system automatically turns the steering wheel for the tractor operator with an electric motor drive using GPS guidance embedded with the guidance and control systems application. Consequently, driving with hands-free guidance allows the operator to easily operate the tractor and improve safety in the field. In fact, keeping line routes in the field which is assisted by the system, the operator can focus on many different tasks in fields, such as spraying or planting and at the same time improve job quality and crop yields. Detailed specifications of tractor and autopilot system are shown in *Tables 1* and *2*. In this study, the tractor was operated on a flat land of 30 m x 30 m size. During the field assessment, the tractor pulled a soil electrical conductivity (EC) sensor implement. The implement is an on-the-go sensor that enable sensing and mapping soil texture, soil organic matter and soil PH. This implement has heavy duty coulter-electrodes attached on a rugged welded steel frame with two free rolling tyres. As the objective of the study was just to assess the straight-line accuracy of an autopilot tractor at various speeds, the soil EC sensor implement was not activated in the evaluation of the tractor. The coulter-electrodes on the sensor did not have contact with soils during the tractor movements. The tractor with the implement just moved on the ground. So there was no significant friction between the coulter-electrodes of the sensor and the ground surface. Meanwhile, a nitrogen sensor for detecting N-crop status was also mounted on top of the operator cab. Similar to the soil EC sensor, this sensor was also not activated.

Three straight-line ropes were laid down on the ground to be tracked by outer right side of front and rear tyres of the tractor which was set to overlay the ropes during the test. Any strip along the straight movement of the outer side of tractor tyres on the ropes was considered as an error. Thus, the ropes were also used as reference measurements for detecting the error of straight forward

TABLE 1
SPECIFICATIONS OF TRACTORS

Section of tractor	*Components*	*Numbers or specifications*
Engine	Number of cylinder/aspiration/valve	4/TI/2
	Emission level	Tyer 3
	Capacity	3 908 cm^3
	Rated horsepower-ISO TR 14396-ECE R120	56/75
	Rated engine speed	2 300 rpm
	Maximum torque – ISO TR14396	298@1400
	Fuel tank capacity	110L
	Service intervals	300 hours
Hydraulic	Main pump flow	36 L/min
	MegaFlow pump flow	48 L/min
	Steering and services pump flow (mechanical/ hydraulic shuttle)	29 L/min
Remote valves	Type	Deluxe
	Maximum no. rear valves	3
	Maximum no. mid mount valves	2
Linkage	Maximum lift capacity of ball end	3 565 kg
	Maximum lift capacity through the range (610 mm behind ball ends)	27 00 kg

movement of the tractor when moving alongside the straight-lines. The levels of tractor engine speeds were set at three different rates i.e. 1 000 rpm, 1 500 rpm, and 2 000 rpm (3.4, 4.2, 5.5 km per hour speed). The autopilot mode was activated with five replications at each speed. The tractor used in this study is shown in *Figure 1*. The GPS guidance setup for tracking the straight-line routes in the field is shown in *Figure 2*. The movement of tractor tyres then was followed closely by 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 spreadsheet software was used in data analysis.

RESULTS AND DISCUSSION

The errors of autopilot mode during testing are shown in *Table 3*. The lowest error in straight-line accuracy of 6.462 cm was found at the highest tractor engine speed level of 2 000 rpm (5.5 km per hour), while the highest error of 38.318 cm was recorded at the lowest tractor engine speed of 1 000 rpm (3.4 km per hour) *(Figure 3)*. Generally, within the three levels of speeds tested, it is concluded that the higher the speed, the lower the error in straight-line accuracy. This finding agrees with Lipinski *et al.* (2016), who reported the actual operating width of the tractor-implement under three travel speeds i.e. 3 km, 6 km and 12 km per hour on cultivated flat land. It was found that increasing the autopilot tractor speed increased

TABLE 2
SPECIFICATIONS OF AUTOPILOT MECHANISM

Aspects of autopilot mechanism	*Components*	*Specifications*
Brand	Trimble	Steering system and plus application
Steering	Steering motor	SAM-200 steering motor
	Connector	IMD-600 to SAM-200 to CAN power cable
System	DC power	Supplied by TM-200, 27 volts, 3.5 Amps
	Processor	1 GHz quad core
	Storage	Primary embedded memory – 32 GB
Mechanical	Dimension	312 x 214 x 45 mm (plus connectors)
	Weight	2.5 kg (5.5 lb)
	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	0^0C to 65^0C
	Storage	-40^0C to 85^0C
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

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 guidance 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.

CONCLUSIONS

A preliminary assessment of straight-line movement of autopilot tractor at various engine speeds i.e. 1 000 rpm, 1 500 rpm, and 2 000 rpm (equivalent to 3.4, 4.2, 5.5 km per hour speed) on Malaysia's flat terrain has been successfully conducted. The preliminary findings of this study showed that the level of tractor speed has a strong relationship with straight-line accuracy while moving in the field. This study in its very

Figure 1 *The autopilot tractor used in this study with nitrogen-sensor on the top of cab and soil EC sensor on the back*

Figure 2 *The setup of GPS guidance system of autopilot mode for tracking the straight-line routes in the field*

preliminary stage has successfully confirmed 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 a great potential to be used in overcoming the problem with regards to inadequate workers in the Malaysian agriculture sector, and also reducing the time usage and operator fatigue, increasing quality of work through enhancing the operator's focus while performing different tasks in agricultural operations with the tractor. The autopilot tractor would be useful for mechanising annual crop/vegetables cultivation on flat land in Malaysia, especially for improving spraying and precise planting operations. Such an automation system is essential for the enhancement of cultivation of annual crops/vegetables on flat land in this

TABLE 3
ERROR IN STRAIGHT-LINE ACCURACY AT VARIOUS ENGINE SPEEDS OF AUTOPILOT MODE

Speed (rpm)	*Error (cm)*					*Mean error (cm)*
	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

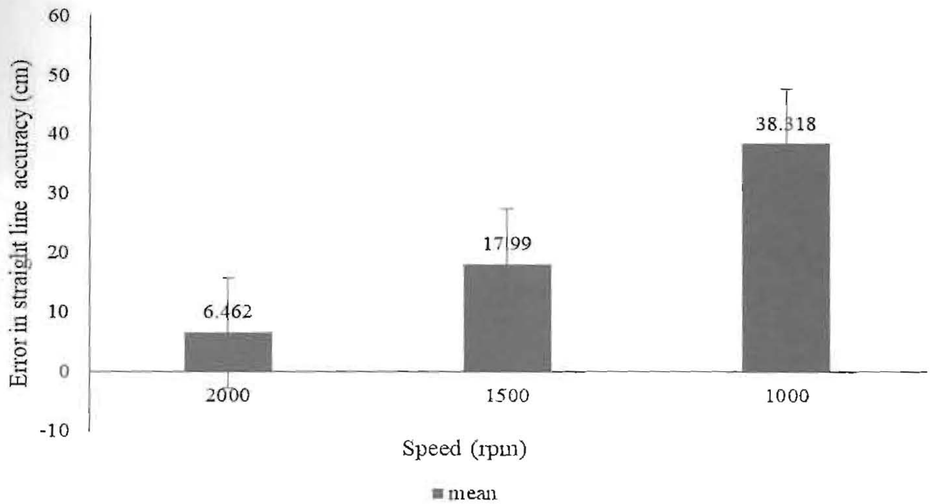

Figure 3 Relationship between tractor engine speeds and error in straight-line accuracy of autopilot in the field

country. The current study is limited to the accuracy of movement of autopilot tractor at various speeds. The study show that the Malaysian environment does not interfere with the accuracy of the autopilot scheme. But before any recommendation is possible, more comprehensive studies in varying terrains, soil conditions and under different operations i.e. spraying, ploughing etc. is needed.

REFERENCES

EASTERLY, D. R., ADAMCHUK, V. I., KOCHER, M. F. and HOY, R.M. 2010. Using a vision sensor system for performance testing of satellite-based tractor auto-guidance. *Computer and Electronics in Agriculture* **72** (2010):107–118.

FAOSTAT. 2018. Machinery. Retrieved from http://www.fao.org/faostat/en/#data/RM.

JAHNS, G. 1997. Automatic guidance of agricultural field machinery. In:*Proceedings of the Joint International Conference on Agricultural Engineering & Technology Exhibition*. Dec. 15-18, Bangladesh, 70-79. http://www.fal.de/<"jahns/papers.html.

LIPINSKI, A. J., MARKOWSKI, P., SEWERYN, L. and PYRA, P. 2016. Precision of tractor operations with soil cultivation implements using manual and automatic steering modes. *Biosystem Engineering* **145** (2016):22-28.

MORGAN, M. and ESS, D. 1997. *The Precision-Farming Guide for Agriculturist*. Moline, IL, USA: Deere & Company. 117pp.

MURPHY, D. 2012. *Agricultural Vehicle Autopilot Roll Over Risk Assessment System*. United States Patent. Patent No.: US 8,275,516 B2. 1-18

SANTOS, A.F. D., CORREA, L. N., GÍRIO, L. A. S., PAIXÃO, C. C. S. and DA SILVA, R. P. 2018. Position errors in sowing in curved and rectilinear routes using autopilot. Engenharia Agrícola, *Jaboticabal*. **38** (4):568-576.

SIEMENS, J., BOWERS, W. and HOLMES, R. G. 2008. *Machinery Management*. Illinois, USA: Deere & Company. 200pp.

SRIVASTAVA, A, K., GOERING, C. E., ROHRBACH, R. P. and BUCKMASTER, D.R. 2006. *Engineering Principle of Agricultural Machines*. 2nd Ed. St. Joseph, MI, USA: American Society of Agricultural and Biological Engineers (ASABE). 588pp.

WEISS, A. 2001. Topographic Positions and Landforms Analysis (Conference Poster). ESRI International User Conference. San Diego, CA, USA.