ISSN: 0974-6471, Vol. 10, No. (3) 2017, Pg. 636-643

Oriental Journal of Computer Science and Technology

Journal Website: www.computerscijournal.org

Development of Program in VB to Compute Tractor Parameters on Automatic Steering

RAGHUVIRSINH PARMAR[1]*, NITIN KARWASRA[1], ASEEM VERMA[1] and BALDEV DOGRA[2]

[1]Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, 141004, India.
[2]Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, 141004, India.

Abstract

A comprehensible computer program is developed in Visual Basic studio to determine the tractor parameters for an automated steering system. Tractor parameters such as real wheel and front wheel trajectory coordinates, clockwise front and rear wheel angle and corrected front and rear wheel angle can be calculated. The input parameters of the developed program are mainly front wheel trajectory data, rear wheel trajectory, distance between front and rear wheel(X_{13}), Tractor velocity vector(V) and Tractor turning angle with center line. The tractor parameters are being calculated with the help of mathematical model which are already fed in program. The developed program successfully calculates the tractor parameters on automated steering system. This developed software could guide an autonomous agricultural tractor in the field. Furthermore, software navigates agricultural tractor both in straight or curved path at normal field operational speed.

Article History

Received: 03 July 2017
Accepted:31 July 2017

Keywords

automatic tractor steering, tractor paraments, vb application, visual basic.

Introduction

Today's Indian agricultural is mechanized in terms of agricultural machinery, new implements but, still required labors or tractor drivers so, we can say that it's not automated yet. That's why next coherent step is automation in Indian agriculture sector. Steering agricultural machinery in fields to perform various production operations is a tedious job for tractor drivers. Agricultural engineers have already started working in the direction of automatic guidance of farm machines. To solve this problem, automated machinery guidance system has been developed to automatically steer the machinery to perform various agricultural operations. In precision agriculture, automated steering system for tractor play a very important role. (Jingtao *et al.,* 2015). The basic requirements for an automated machinery guidance system include detecting the tractor position; planning for an optimal path for the machinery carefully without damaging the crop and

CONTACT Raghuvirsinh Parmar parmarraghuvir-fmpe@pau.edu Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, 141004, India.

To link to this article: http://dx.doi.org/10.13005/ojcst/10.03.12

accurately steering the tractor along the desire path. The automated steering system can reduce drive fatigue which results in increase in both productivity and safety of the operation. In terms of functionality. Automated steering system are classified into the two types which are operator-aided systems and autonomous systems. In first system only human driver is guiding the tractor on the desire paths; while in second types of system replaces the human driver to perform all field operations. Also, sometimes combining above both types of system.

Automatic steering has advantages like, repeatable path tracking, full use of the implement's effective width, reduction in overlapping and ease in operation during night time or during low visibility conditions (Holpp *et al.,* 2013). Automatic steering also lowers the costs of agricultural operations (Shinners *et al.,* 2012). The profits generated by automatic steering systems in agricultural machines are determined mainly by the quality of operation (Dunn *et al.,* 2006).

Mostly global positioning system (GPS) is used as navigation sensor. Researchers could guide an agricultural tractor on desired path with real time kinematic GPS based navigation system (Bell,2000). But they have higher percentage of error. To reduce it an inertial measurement unit with an RTK- GPS to provide more accurate navigation information was developed. That could guide tractor performing all field operations including planting cultivating and spraying on both straight and curved paths (Kise *et al.,* 2001, 2002).

Sensors can detect a path in the field. Vision- based guidance can be used to guide the agricultural tractor which can perform various operations (Benson *et al.,* 2003). Numbers of researchers has reported attempts to improve the reliability of pathway determinations for vision based guidance systems. Hague and Tillett (2001) used a bandpass filter to find the path.

Gilmour (1960), Brooke and David (1968), MacHardy (1967), Rushing (1959) have looked into the use of different path guidance systems. Richey (1959), Liljedahl and Strait (1962), Parish *et al., (*1970*)*, Grovum and Morris (1968) have investigated different types of control mechanisms. However, little attention has been paid on effect of tractor parameters on automatic steering. Many of the design factors used for modern tractors, e.g., visibility, operator comfort and control location have little bearing on the design of an automatic tractor (Shukla *et al.,*1970).

According to Moncaster and Harries, (1984) the basic need for automatic control of agricultural steering system to increase efficiency of field operation. An automatic guidance system for agricultural tractors should be authentic, flexible, simple to operate , easy to maintain and versatile (Grovum and Zoerb, 1970).

The major advantage of the software is that by accurately controlling the straight or curved paths of agricultural tractor, the width of coverage and soil compaction in the soil can be minimized. A real-time guidance system is required to keep field equipment operating only on the predetermined paths.

The aim of this study was to develop computer program using visual basic software on the basis of mathematic modelling which has already been developed by various scientists. That mathematical modeling shows the relationship between tractor parameters and automatic steering accuracy. The findings of the study can help in determining various tractor parameters in automated steering system on predefine curve path. So, software can easily help in calculating the tractor steering parameters while the tractor is turning.

Materials and Methods

Mathematical Model

A model was developed carrying the relationship between tractor parameters, speed and tractor position (Shukla *et al.,* 1970). In the first-place model was little bit complex, but after assumptions like operation on a plane surface at low speed so that inertia and soil reaction forces could be neglected. The various annotations used in developing the mathematical model and its schematic diagram is shown in Fig. 1.

Some few assumptions were taken in tractor all wheel that tends to make a clockwise turn (Fig. 1) were considered positive angle value. Also, an anti-

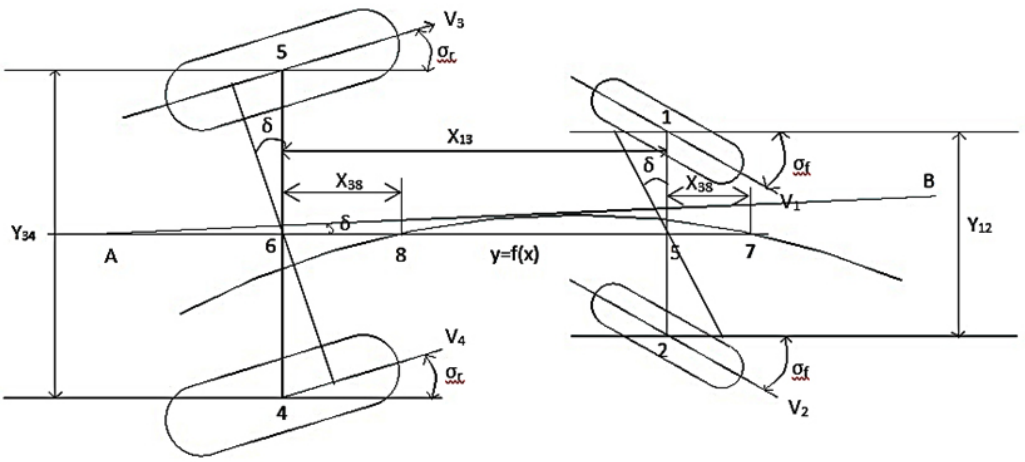

Fig. 1: The schematic diagram used in developing the mathematical model of steering system

clockwise turn was considered as negative value. These mathematical models were developed back in earlier days so, all units used were feet, seconds and radians.

For simplification time derivatives was used as the dot notation shown as per follow,

$X_8 = dx_8 / dt$

But for this research work we took was static so, that the above equation haveX_8 equal to X_8. From Fig. 1 rear wheel geometry of agricultural tractor,

$X_8 = V_3 \cos(\sigma_r - \delta) - [\{(0.5 Y_{34})^2 + (X_{38})^2\}^{0.5} \cos(\delta - \arctan(2 \times X_{38} / Y_{34})] \times \delta$ ...(1)

$Y_8 = V_3 \sin(\sigma_r - \delta) - [\{(0.5 Y_{34})^2 + (X_{38})^2\}^{0.5} \sin(\delta - \arctan(2 \times X_{38} / Y_{34})] \times \delta$ ...(2)

From Fig. 1 front wheel geometry of agricultural tractor,

$X_7 = V_1 \cos(\sigma_f - \delta) - [\{(0.5 Y_{12})^2 + (X_{17})^2\}^{0.5} \cos(\delta - \arctan(2 \times X_{17} / Y_{12})] \times \delta$ ...(3)

$Y_7 = [\{(0.5 Y_{12})^2 + (X_{17})^2\}^{0.5} \sin(\delta - \arctan(2 \times X_{17} / Y_{12})] \times \delta - V_1 \sin(\sigma_f - \delta)$ ...(4)

Also, we can write from Fig. 1

$\delta = V_3 \sin(\sigma_r) + V_1 \sin(\sigma_f) / X_{13}$ ...(5)

For a four-wheel drive tractor, the tractor velocity (V) was considered known and the velocities of the front wheel (V1) and rear wheels(V3¬) were calculated from equation (6) and equation (7):

$V_1 = v / \cos(\sigma_f)$ ...(6)

$V_3 = v / \cos(\sigma_f)$ ...(7)

For the automatic steering system of agricultural tractor, the response from the steering was considered to be a function of the error. For front wheel steering system, the front steer angle was considered as a function of the front tracking error, which is denoted by l_f, i.e.:

$\sigma_f = g_f(l_f)$ ...(8)

In this four-wheel steering system, if we are trying two points on the path of the vehicle, the rear steering angle was a function of the rear tracking error, which is denoted by $l_{r,}$ i.e

$\sigma_r = g_r(l_r)$ ...(9)

Even if, for rear wheel steering, for an example a self-propelled combine harvester, the steering response was a function of the error at the front,

$\sigma_r = g_r(l_f)$ ...(10)

In this research, a relative relationship between computer error and steering response was used.

Steering Geometry

Related to steering from the starting it was assumed that the tractor had perfect steering geometry, the developed mathematical model equations were used only when the agricultural tractor was turning counter clock wise whereas when the tractor was turning clockwise, eqn. (11) developed by Schilling (1960) and by Shukla *et al.,* (1970) were used depending upon the type of steering. Schilling's equation is as follows

$$Tan(\sigma_{f1}) = \frac{X_{13}\tan(\sigma_f)}{X_{13}+Y_{12}\tan(\sigma_f)} \quad ...(11)$$

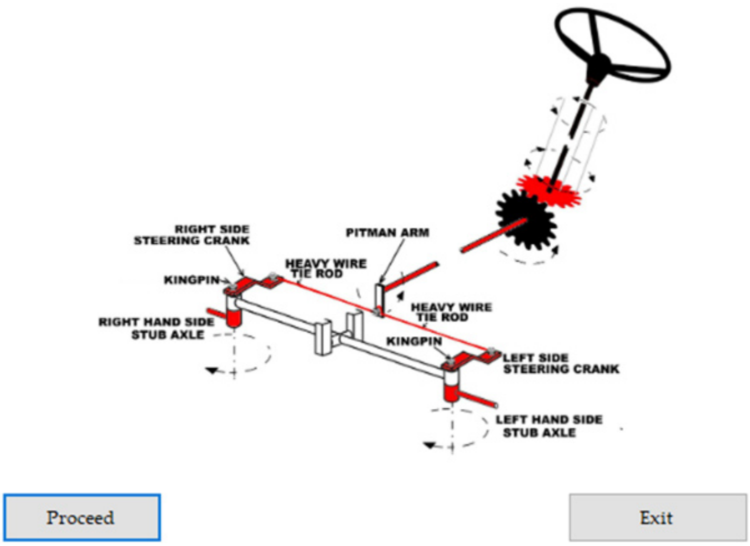

Fig. 2(a) Welcome screen of the developed program

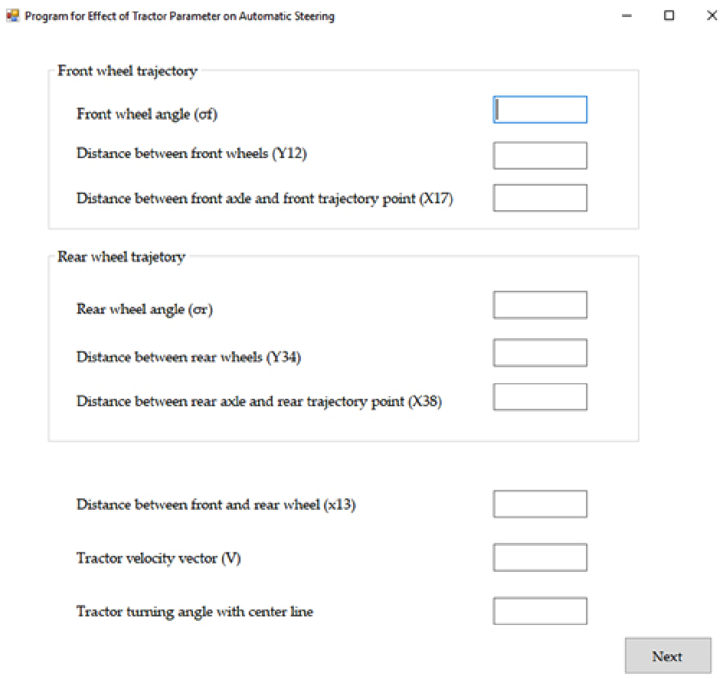

Fig. 2(b) Input screen of the developed program

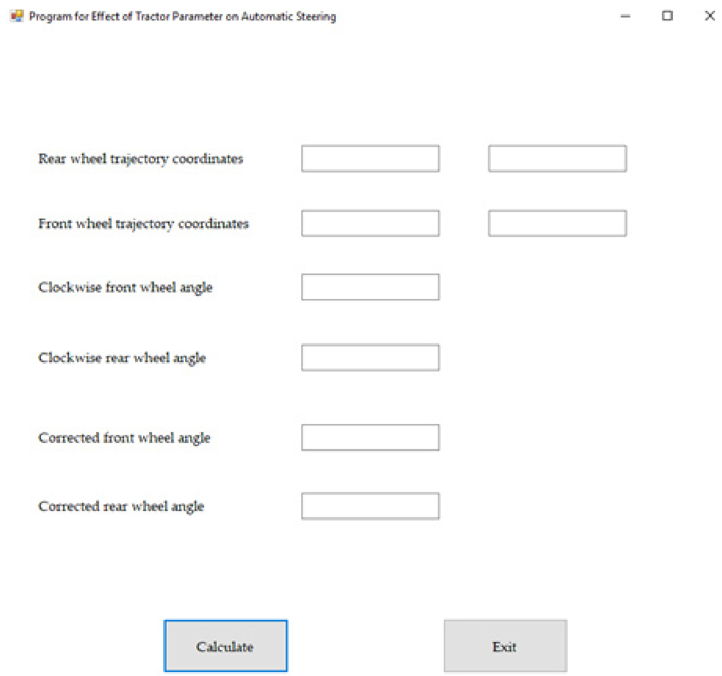

Fig. 2(c) Output screen of the developed program

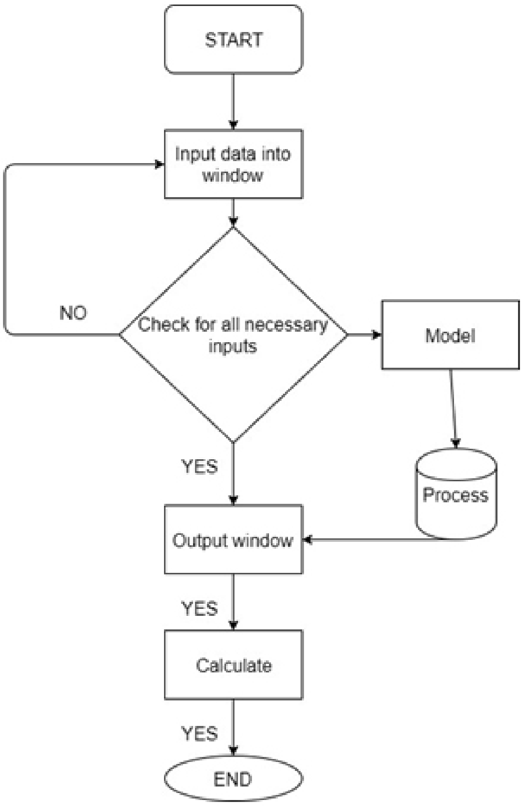

Fig. 3: Flow chart of the developed program

Where, σ_{f1} = turning angle of the outside front wheel.
In case of front wheel steering equation (11) used. For rear wheel steering, a similar version of Schilling's equation was used as follows:

$$Tan(\sigma_{r1}) = \frac{X_{13}\tan(\sigma_r)}{X_{13}+Y_{34}\tan(\sigma_r)} \quad ...(11\ a)$$

Where, σ_{r1} = turning angle of the outside rear wheel.

The Schilling's equation was very useful to see the effect of steering geometry. That's why it was added to mathematical model. For any turn, the point of turning is called where the center line of all wheel axles must intersect in a common point. A wheel nearest the center of turning must have a steeper turning angle than a wheel farther from the center of turning. Hence, radius of turning, the left front wheel would have a more outrageous tuning angle for a counter wise turn than for a clockwise turn. Schilling's equation was used to reduce the turning angle of the left front wheel when it was an outside wheel. Similar points out enforce to the rear wheels for rear wheel steering geometry.

Table 1: Input parameters

Inputs	Data
Front Wheel Trajectory	
Front wheel angle (σ_f)	30
Distance between front wheel (Y_{12})	1.2
Distance between front axle and front trajectory point (X_{17})	0.5
Rear Wheel Trajectory	
Rear wheel angle (σ_r)	10
Distance between rear wheel (Y_{34})	2.5
Distance between rear axle and rear trajectory point (X_{38})	0.7
Other tractor related parameters	
Distance between front and rear wheel (X_{13})	3.5
Tractor velocity vector (V)	30
Tractor turning angle with center line	60

Drawback of Schilling's equation is not able to handle the example of four-wheel steering if any degree of error is present in steering geometry. For example, if the vehicle is translating crabwise as well as turning. To handle the general case of four-wheel steering, the following equations were developed by Shukla *et al.,* (1970):

$$Tan\ \sigma_{r1} = \frac{\tan(\sigma_r)}{1 - \frac{Y_{34}(\tan(\sigma_f)+tan(\sigma_r))}{X_{13}+C\times\tan(\sigma_f)}}. \quad ...(12)$$

$$Tan\ \sigma_{f1} = \frac{(X_{13} - C\times\tan(\sigma_r))\tan(\sigma_f)}{Y_{12}(\tan(\sigma_f)+tan(\sigma_r))} + c \times \tan\sigma_r - X_{13} \quad ...(13)$$

Where, C= $(Y_{34}-Y_{12})/2$

To find out whether the tractor was turning clockwise or counterclockwise, crabbing sidewise only, or traveling straight ahead a comparability task carried out which gives the directions and magnitudes of the turning angles of the left front and left rear wheels. This equivalence was made continually and equation (12) and (13) were inserted into the analysis whenever the vehicle was making a clockwise turn.

Input Parameters

The input parameters for the developed computer program are mainly divided in two parts, namely front wheel trajectory and rear wheel trajectory. The inputs include Front wheel angle (σ_f), Distance between front wheel (Y_{12}), Distance between front axle and front trajectory point (X_{17}), Rear wheel angle (σ_r), Distance between rear wheel (Y_{34}) and Distance between rear axle and rear trajectory point (X_{38}), Distance between front and rear wheel (X_{13}), Tractor velocity vector (V) and Tractor turning angle with center line. Beside the input group, the equations which are derived by Shukla *et al.,* (1970) were used in the program. The program window for input parameter is shown in Fig. 2(b). The input data as per parameters discussed was taken only for indication purpose. For automated steering parameters calculation, i.e. rear wheel trajectory coordinates, front wheel trajectory coordinates, clockwise front wheel angle, clockwise rear wheel angle, corrected front wheel angle, and corrected rear wheel angle, a separate output form is created which is shown in Figure 2(c). The flow chart of the developed program is shown in the Figure 3.

Results and Discussion

General inputs of software were taken from the previous researcher data and general considerations. In the present study, the indicative data is tabulated in Table 1. The software output for these runs is given in Table 2. Table indicates that the developed program is capable of calculating all components of automated steering system for tractor on curved path which is given or predefined.

Ismail *et. al.,* (2012) developed similar kind of software for autonomous tractor in agricultural application and it work successfully. In that whole system include ICP- CON controller module and

Table 2: Output parameters calculated by developed software

Output	Data
Rear wheel trajectory coordinates	X= -103.776 Y= -23.477
Front wheel trajectory coordinates	X= -122.863 Y= -188.345
Clockwise front wheel angle (^{0})	1.1557
Clockwise rear wheel angle (^{0})	0
Corrected front wheel angle (^{0})	-0.09393
Corrected rear wheel angle (^{0})	-0.22138

mechanical relay and whole project was developed by using Microsoft Visual Basic to design software. The same kind of technique is also mentioned by Ismail *et. al.,* (2011) which used a camera vision with color detection for the variable rate technology (VRT) automated sprayer. They develop visual basis base software to detect green leaves.

Conclusion

The developed software is capable to calculate various tractor parameters on automated steering system and can calculate real wheel and front wheel trajectory coordinates, clockwise front and rear wheel angle and corrected front and rear wheel angle. This could be helpful in guiding the tractor, with acceptable precision for field operations, with more accurate position. A mathematical model based upon a variable steering rate might improve the stability of the guidance system with microcomputer base system. Some further improvements can be done by real field operation.

Reference

1. Bell, T. Automatic tractor guidance using carrier-phase differential GPS. *Comp. and Elec. in Agri.,* 2000; 5(1–2): 53–66.
2. Benson, E.R., Reid, J.F., Zhang, Q. Machine vision-based guidance system for agricultural small-grain harvester using cut-edge detection. *Biosystems Eng., 2003; 86*(4): 389–398.
3. Brooke, David, W. Off-the wire guidance for leader cable vehicles. *Trans. of the ASAE*:, 1968; *68*: 819.
4. Dunn, P.K., Powierski, A. P., Hill, R. Statistical evaluation of data from tractor guidance systems. *Precision Agriculture., 2006; 7*(3):179-192.
5. Gilmour, W. D. An automatic control system for farm tractors. *Jr. of Agri. Eng. Res., 1960;* 418-432.
6. Grovum, M.A., Zoerb, G.C. An automatic guidance system for farm tractors. *Trans. of the ASAE., 1970; 13*(5):565-573.
7. Grovum, Morris, A. An automatic guidance system for farm tractors. Unpublished M.S. Thesis Dept. of Mech. Eng. Univ. of Saskatchewan, Saskatoon, Canada., 1968.
8. Hague, T., Tillett, N.D. A bandpass filter-based approach to crop row location and tracking. *Mechatronics., 2001; 11*(1):1–12.
9. Holpp, M., Kroulik, M., Kviz, Z., Anken, T., Sauter, M., Hensel, O. Large-scale field evaluation of driving performance and ergonomic effects of satellite-based guidance systems. *Biosystems Eng., 2013; 116*(2): 190-197.
10. Ismail, W.I.W., Hudzari, R. M.M., Ridzuan, M.N. Development of Variable Rate Sprayer for Oil Palm Plantation. *Bulletin of the Polish Academy of Sciences Technical Science,* 2011; 59(3): 299-302.
11. Ismail, W.I.W., Hudzari, R.M.M., Saufi, K. M., Fung, L.T. Computer-controlled system for autonomous tractor in agricultural application. *Journal of Food, Agriculture & Environment,* 2012; 10(2): 350-356.
12. Jingtao, H., Lei, G., Xiaoping, B., Taochang,

L., Xiaoguang, L. Review of research on automatic guidance of agricultural vehicles. *Trans. of the Chi. Soc. of Agri. Eng.*, 2015; 31(10), 1-10.

13. Kise, M., Noguchi, N., Ishii, K., Terao, H. Development of agricultural autonomous tractor with an RTK-GPS and a FOG. Proceedings of The Fourth IFAC Symposium on Intelligent Autonomous Vehicles, Sapporo, Japan.,2001; (99–104).
14. Kise, M., Noguchi, N., Ishii, K., Terao, H. The development of the autonomous tractor with steering controller applied by optimal control. Proceedings of Automation Technology for Off-Road Equipment, Chicago, USA., 2002; (367–373).
15. Liljedahl, L.A., John, S. Automatic tractor steering. *Agri. Eng., 1962; :43*(6):332-335.
16. MacHardy, F.V. An automatic guidance system for farm tractors. *Canadian Agri. Eng., 1967; 9:*17-19.
17. Moncaster, M.E., Harries, G.O. Automatic control of tractors and field machines. In Proceedings of the first international conference on robotics and intelligent machines in agriculture. *ASAE Publication, 1984; 4*-84:120-127.
18. Parish, Richard, L., Goering, C.E. Developing an automatic steering system for a hydrostatic vehicle. *Transactions of the ASAE., 1970; 13*(4): 523-552.
19. Richey, C.B. Automatic pilot for farm tractors. *Agri. Eng., 1959; 40*:2: 78-79.
20. Schilling, E. The geometry of steering mechanism of tractors. Land technische Forschung, 1960; 10(1).
21. Shinners, T.J, Digman, M.F., Panuska, J. C. Overlap loss of manually and automatically guided mowers. *Applied Eng. in Agri., 2012; 28*(1): 5-8.
22. Shukla, L.N., Carroll, E.G., Day, C.L. The effect of tractor parameters on automatic steering. Diss. University of Missouri, Columbia, 1970.