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Misalignment between sugar cane transshipment trailers and tractor

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Abstract. *Sugarcane production system is dependent on a continuous cutting and regrowth of cane plants from their roots, on which traffic should be avoided to ensure the physiological integrity of regrowth and productivity. This need for accuracy in sugarcane machine traffic boosted the adoption of automated steering systems, especially on harvesters. Tractors with the transshipment trailers, which continually accompany the harvesters in the field, yet do not adopt it or use technology with lower positioning accuracy. The goal of this study is to evaluate the patterns of lateral deviations occurring in transshipment trailers during harvest in straight and curved paths. We used a combination of a tractor and two transshipment trailers with three axles each. The tractor and trailers were each equipped with a GNSS receiver with RTK correction and the deviations of each trailers relative to the tractor were measured taking as a reference the line projected paths. The results show that the errors are far from accepted and 538% higher for curved paths than when in straight paths and that the major cause of deviations are the tractors that drive the whole set, showing the necessity of further studies involving more variables.*

Keywords.
Lateral deviation, harvest, sugarcane.

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INTRODUCTION

Brazil is the largest producer of sugarcane, sugar and ethanol. According to Valdes (2011), the area cultivated with sugarcane expanded from 4.3 million hectares in 1999 to more than 10 million hectares in 2010.

The sugarcane production system is dependent on a continuous cutting and regrowth of cane plant from their roots, on which traffic should be avoided to ensure the physiological integrity of regrowth and productivity (PAULA & MOLIN, 2013). Therefore the traffic of wheeled machines during harvesting must follow exactly crop lines, a process that is hampered when harvesting in night shifts (BAIO, 2011), and the limited margin of allowed misalignments to prevent damage to the root system (SPEKKEN et al., 2014). As stated by Baio (2007), the asymmetric of sugarcane rows is a major cause of traffic damage associated with the harvest.

A method that enables harmonization between wheel sets and plants is known as controlled traffic system (MASEK, 2014). The main peculiarity of this technique is the permanent distinction between the use of areas for root growth and those used for the traffic of rolling elements (traffic zones).

Tools are required to ensure that the wheels travel in a certain area, helping to ensure that the operations in the field are strictly parallel, without the exclusive dependence of operator skills (MOLIN et al., 2011). Equipment and aid resources to the operator to go on parallel paths has evolved significantly. No doubt the use of GNSS system meant great advances in this direction, especially with automatic steering equipment with sensors and actuators that drive the vehicle.

Some sugarcane mills has been using automatic steering equipment hydraulic actuator correction signal usually by RTK (Real Time Kinematic) in harvesters. But in tractors on the transshipment trailers do not use auto steering solutions or use technology with lower positioning accuracy. In addition, the trailers suffer deviations caused by curves and slopes, which often occurs in the producing areas.

The performance of the automatic steering systems is often associated with transverse errors to the path, attributed to factors such as vehicle dynamics, geographic position error, pulled equipment, operating environment, etc. (EASTERLY et al., 2010).

The goal of this study is to evaluate the patterns of lateral deviations occurring in transshipment trailers during harvest in straight and curved paths.

MATERIAL AND METHODS

The study was conducted in sugarcane production areas located in the western part of Sao Paulo state, in fields under clay soil and the average yield for first cut 150 Mg ha^{-1}. The rows were previously projected based on the topographic survey. The experiment was divided into two areas: A1: straight path (12.05 ha) and A2: curved path (15.95 ha).

A JD 6180J tractor (John Deere, Montenegro, Brazil) was used and two trailer transshipments TAC 14000 (Civemasa, Matao, Brazil) with carrying capacity of 16 tons each, with three axles.

Both the tractor as each of the trailers had a GNSS receiver with RTK correction for determining instant positioning. The transshipment trailers used X30® datalogger (Topcon, Tokyo, Japan) and FMX® (Trimble, Sunnyvale, USA) and the tractor used FMX® (Trimble, Sunnyvale, USA) with hydraulic actuator. The antenna inclination corrections are performed by the device itself since this has been configured according to the dimensions of each part of the set.

Figure 1 shows the arrangement of antennas and datalogger coupled to the transshipment trailers and tractor.

Figure 1 - Schematic representation of the arrangement of GNSS antennas in the set

On sugarcane harvesting, the machines are divided by harvesting groups consisting of 6 harvesters and approximately 1.7 tractor and trailers transshipment sets per harvester, and these are not tied to only one harvester.

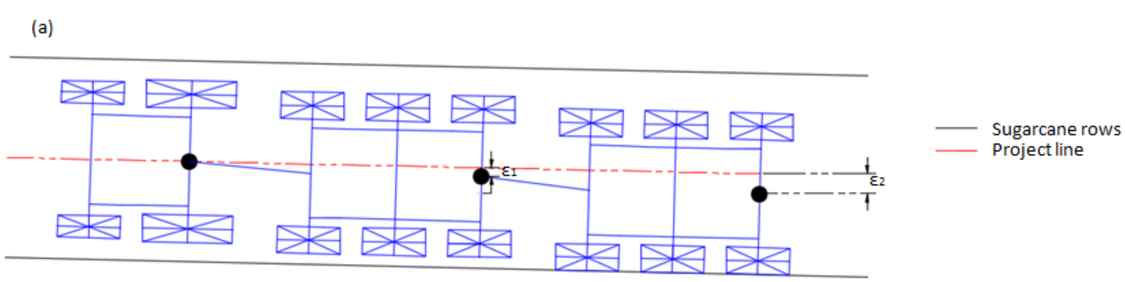
The average of the set speed (harvester and tractor with transshipment trailers) was approximately 1.25 m s^{-1}. Data collection was continuous under acquisition frequency of 0.5 Hz.

During the data collection, the number of satellites varied between 12 to 16, and the dilution of precision was less than 4, meaning that, there were no effects of ionospheric scintillation or shading that could interfere with the results. The RTK base was 2 km from the experimental area.

Data were orderly using AutoCAD® Map 3D (Autodesk, San Rafael, USA) and QGIS® 2.14 (Open Source Geospatial Foundation, Beaverton, USA) cutting edges, collector shutdown for interruptions or signal losses keeping approximately 25% of the total data collected.

Parallelism errors (deviations) were evaluated by the difference of the orthogonal distance between the position of the antennas in the center of the tractor and for each trailer and the reference line, originated upon the furrows project, using an automated algorithm developed by Spekken et al. (2014).

The error path of each part of the set was obtained, from which was defined displacement of the articulated set, such that when correlated with the studied paths allowed to understand the misalignments as a function of axis position, the routing and sloping terrain conditions. The ε deviations from the path are represented in figure 2, where, for example, ε1 is the deviation undergone by the last axle of the first trailer and ε2 is the deviation undergone by the last axis of the second trailer.



(b)

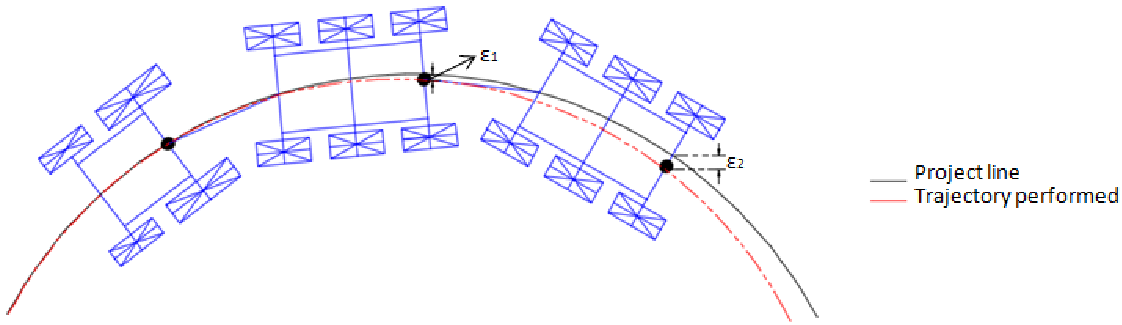


Figure 2 - Graphical representation of the relative position of the axis in relation to the reference (deviations) in straight path (a) and curved path (b)

The computed errors correlating the centerline of each transshipments trailer relative to the tractor front axle centerline and the analysis of these was performed by descriptive statistics, obtaining the average, median, and standard deviation of the error. The idea is to capture possible trajectory patterns specifically the centerline of each of the transshipment in relation to the tractor front axle centerline and between each transshipment.

RESULTS AND DISCUSSION

The results presented in Table 1 show the errors acquired from each of the set (tractor front axle, third axle transshipment trailer 1 and third axle transshipment trailer 2) through the collection of data considering straight path (Area 1). Based on these data, the cumulative frequency plot (probability) of the errors were generated. The data of the harvester were considered for the observation of eventual trajectory errors linked to this and could influence the displacement of the set.

Table 1. Parallelism errors for each axles of tractor and trailers transshipments submitted to straight path (A1)

Analysis	Equipament			
	Tractor	Axle 3 transshipment trailer 1	Axle 3 transshipment trailer 2	Harvester
N	836	800	813	1183
Minimum error (m)	0.001	0.001	0.001	0.001
Maximum error (m)	0.177	0.484	0.590	0.397
Average error (m)	0.083	0.109	0.129	0.050
CV (%)	61.57	72.14	75.97	174.83
Standard deviation (m)	0.051	0.079	0.098	0.087
2σ (m)	0.185	0.267	0.326	0.225

N: number of collected point; 2σ: 95% probability error; CV(%): coefficient of variation

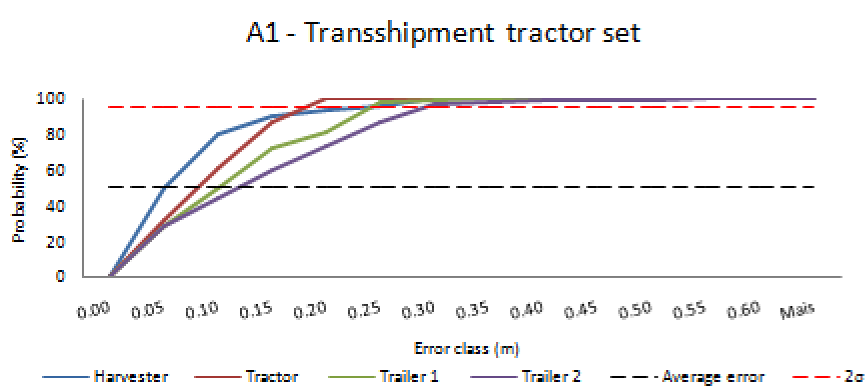


Figure 1 - Probability of errors acquired for each of the tractor- transshipment trailer set in area 1

The same was done for the Area 2, which contemplated the curved path as shown in table 2 and figure 2.

Table 2. Parallelism errors for each axles of tractor and trailers transshipments submitted to curved path (A2)

Analysis	Equipament			
	Tractor	Axle 3 transshipment trailer 1	Axle 3 transshipment trailer 2	Harvester
N	1600	2103	2334	2012
Minimum error (m)	0.054	0.001	0.001	0.001
Maximum error (m)	1.490	1.483	1.496	1.491
Average error (m)	0.447	0.533	0.549	0.079
CV (%)	52.57	68.11	82.45	253.01
Standard deviation (m)	0.270	0.300	0.353	0.148
2σ (m)	0.919	1.133	1.255	0.375

N: number of collected point; 2σ: 95% probability error; CV(%): coefficient of variation

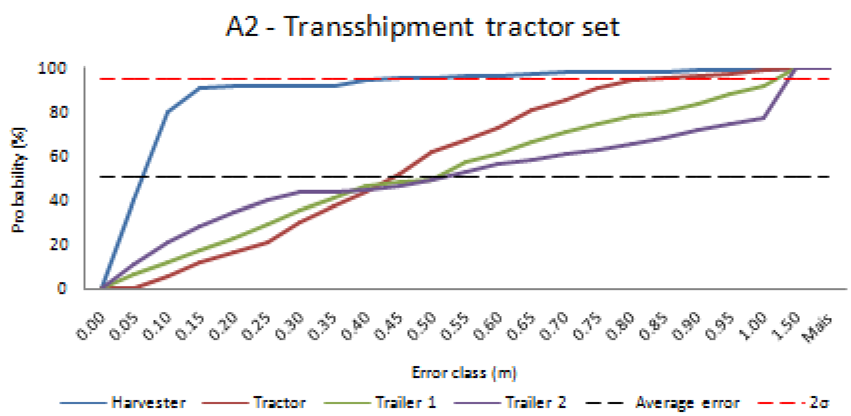


Figure 2 - Probability of errors acquired for each of the tractor- transshipment trailer set in area 2

Errors between tractor front axle and projected path and between it and third axle trailers were out of a limit that could be accepted for a good traffic control. Sugarcane producers consider it at around 0.1 m when deciding for investment on auto steering to avoid ratoon damages. Table 3 shows the parts of the set, considering the centerline of each of the transshipment in relation to the tractor front axle centerline and to the projected lines. These values show that when comparing the tractor front axle error values to the projected line on the area with the straight path (A1) with the curved path area (A2), the errors were 538% higher in A2 than in A1. This high difference between the errors is due to the influence of types of routes that the set was subjected. Incurved paths, the set moves closing the radius. In addition, variables such as topography of the area directly influence the increase of this error. Between first and second trailer transshipments errors were lower, which can be explained by the distance between them being smaller than between tractor and first trailer. It is clear that solutions have to be found for reducing the transversal positioning axels errors along the set.

Table 3 – Relative deviations among axels

Area	Error between the part (m)			
	Tractor - reference	Trailer 1 - tractor	Trailer 2 - tractor	Trailer 2 - Trailer 1
A1	0.083	0.026	0.046	0.020
	(538%)	(373%)	(221%)	(- 80%)
A2	0.447	0.086	0.102	0.016

It was observed that, despite deviations being greater in the last trailer, largest errors are found in the tractor, which drives the set. It should be noted that the harvester was using automatic steering system, which helps on decreasing transverse error trajectory of the trailers as these depend on the harvester path to prevent accidents with its elevator (Baio, 2012).

CONCLUSION

Errors between tractor front axle and projected path and between it and third axle trailers are out of any acceptable limit. The higher errors are found on curved paths, with 538% higher deviations of the tractor than on straight path. Further studies are necessary, involving guidance types and side inclination effects.

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