Precision Evaluation of GPS based Autonomous Agricultural Vehicles using Computer Vision

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Abstract*—Technological advances have been successfully achieved in precision agriculture using autonomous agricultural vehicles. Among these advances, the increase of efficiency and productivity in field operations can be highlighted. Several autonomous driving systems are implemented using the GPS RTK system, which allows operations to centrimetric accuracy. However, irregularities in ground conditions, tractor traction, wheel slip and operating speed may influence the performance of GPS based autonomous agricultural vehicles. In this way, the evaluation of the autonomous driving systems becomes essential to the achievement of high precision levels in field operations. This evaluation can be performed by measuring the displacements using locally installed sensors in the vehicle, such as: cameras, lasers, odometer, ultrasonic sensors, among others. Among the local sensing options, it is well-know that computer vision methods allow the location of any system in the space. Nevertheless, these methods demand the adjustments of their parameters to ensure high accuracy. In this way, the objective of this work is to evaluate the precision of an agricultural vehicle in an autonomous condition using computational vision methods and image processing techniques. Tracking localization by matching key points in digital images can be exploited in order to assess the location of the vehicle during its work in the field. The outcome of this proposal can be evaluated to infer conclusions about the accuracy of the autopilot system. The vehicle under study is a Massey Ferguson 7350 with the Auto-Guide 3000 autopilot system with GPS RTK correction signal. The computer vision system consists of two Canon Rebel T5 cameras with focal lens of 50 millimeters. The image processing was performed using a corners' detector technique developed in a grid image in the field. The manuscript details the camera's calibration and the vehicle's localization procedures. The main conclusion of this work is that computer vision can be successfully exploited for aiding the autonomous driving of agricultural vehicles if devices, procedures and parameters are well selected.

Keywords*— *Computational vision; Image processing; RTK GPS Navigation; Smart vehicles; Precision agriculture.

I. INTRODUCTION

Technological advances have been successfully achieved in precision agriculture using autonomous agricultural vehicles. Among these advances, the increase of efficiency and productivity in field operations can be highlighted. Several autonomous driving systems are implemented using the GPS RTK system, which allows operations to centrimetric accuracy. Nevertheless, some errors of the GPS system during the autonomous driving are unavoidable and are always presented. In this way, the evaluation of the accuracy of autonomous driving systems becomes essential to the achievement of high precision levels in field operations.

The objective of this investigation is to track the location of an agricultural vehicle during an autonomous operation, in order to evaluate the accuracy of the autopilot system in a real environment. The vehicle under study in this project is a Massey Ferguson 7350 with the Auto-Guide 3000 autopilot system with GPS RTK correction signal. This tracking is performed by exploiting computer vision methods. In order to do so, an image of a grid, as illustrated in Fig. 1, is hanged in the field. Several digital images are acquired by the computer vision system that consists of two Canon Rebel T5 cameras with focal lens of 50 millimeters. The computer vision method used in this work has been developed by [1]. This technique can detect key points in digital images based on the local characteristics and on the grid line architecture of a planar checkerboard, as illustrated in Fig. 1. For each image, the corner point locations are firstly identified. These locations are then used to determine the intrinsic and extrinsic parameters of the camera with photogrammetric method. This method is a well-developed and reliable method for estimating camera intrinsic parameters [1,2]. The mapping of the location of the vehicle at each frame is performed by exploiting the camera pinhole model [1]. A pinhole camera is a simple camera without lens and with a single small aperture. The parameters previously calculated are represented in a 4x3 matrix called pinhole camera matrix. This matrix maps the 3-D world scene into the image plane. The intrinsic parameters represent the optical center and focal length of the camera. The extrinsic parameters represent the location of the camera in the 3-D scene. This strategy proves to be effective for mapping the location of the vehicle as illustrated in Fig. 2.

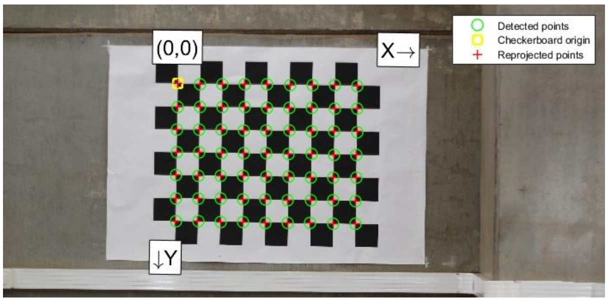

Fig. 1. Detection of key points in a grid in digital images

II. EXPERIMENTAL PROCEDURE

During an autonomous operation, the autopilot is set to guide the vehicle in a straight line and the cameras are used to the acquisition of several digital images. The location of the vehicle can be calculated using the pinhole camera matrix model. Several vehicle's locations are illustrated in Fig. 2.

III. RESULT AND DISCUSSION

The objective is to assess the accuracy perception of the visual system, as performed by [1]. Table 1 shows the accuracy of the system in a plane XZ (Planar accuracy) as well the accuracy in the dimensions X, Y, Z (Stereo Accuracy) considering different distances from the grid image.

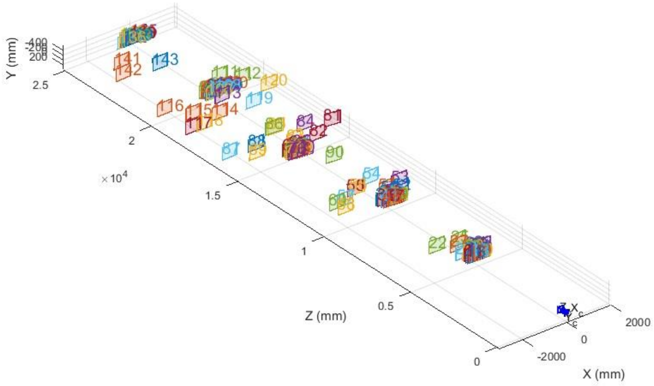

Fig. 2. Mapping the location of the vehicle

Table I. Perception Accuracy

Maximum distance (m)	Accuracy	
	Planar (%)	Stereo (%)
5	82,45	80,84
10	87,22	85,81
15	95,3	83,64
20	73,81	66,93
25	56,11	44,96

IV. CONCLUSIONS

The computer vision method allows mapping the vehicle's localization using a grid image in the field. The distance between the vehicle and this image should be less than 25 meters.

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