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Automatic Positioning System of Small Agricultural Robot

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Abstract. The present article discusses automatic positioning systems of agricultural robots used in field works. The existing solutions in this area have been analyzed. The article proposes an original solution, which is easy to implement and is characterized by high-accuracy positioning.

Introduction

Automatic motion control systems and parallel driving systems find wider application in production of agricultural machinery. These systems include electronic and hydraulic components to drive vehicles. Machinery can operate in fields using automatic pilot, however operator's work is still needed in this case. Operator helps machinery to turn, and levels out the route at significant deviations; in all other situations load on operator is reduced. Accurate field works completion enables to reduce time expenditure and overwork by 10%. It also allows saving fuel and spending mineral fertilizers reasonably. Processing of fields with herbicides becomes more effective. All the known automatic piloting systems imply mounting of direction indicator, controller and signal receiver of global satellite positioning GLONASS or GPS [1,2,5]. Scientific literature contains solutions based on using machinery vision systems for navigation [3,4], as well as integrated complex control systems including machinery of different use and controlling complex [6]. All the mentioned facilities are preferable when processing fields are large and boundless and minimum obstacles are observed. However accuracy of satellite navigation positioning without adjustment is known to be 10-15 meters. Thus it makes it hard to use them in agricultural machinery working on patches of land up to 1 hectare, particularly in rural areas where the territory is strictly divided between the land owners. Differential corrections obtained from geostationary satellites or from ground base stations are generally not provided for free and thus cannot be an option for agricultural machinery of small size.

Suggested solutions

When developing autonomous control system of agricultural robot one needs to define positioning and navigation concept. For that purpose the main checklist of algorithms of manual and automatic motion control should be developed. Robot system is to possess the following driving modes:

1. Remote manual control by operator through radio channel. Such control system should be able to give commands to onboard computer up to the distance of 500 m. The mentioned

commands are: start/stop engine, select direction “forward/backward”, start/stop motion, wheel turn left/right. In this case operator is to monitor all the movements through video cameras mounted on the robot.

2. Automatic control enables the operator to set guiding points at the computer while the system calculates motion trajectory taking into consideration the complexity of land terrain. While soil processing it should also consider plowing modes (conventional, round, and flat).

Autonomous positioning system of agricultural robot can have a number of solutions. Simple and effective one is monitoring the robot position according to four tracking devices with infrared transmitters which are preliminary mounted on the angles of trapezoidal area. Each of the tracking devices generates original digital code. Infrared receiver with accurate rotating mechanism and narrow aspect angle in a horizontal plane is fixed on the robot body.

At the definite key moments the robot stops and coordinates its location in accordance with tracking devices. Information from indicators considering trajectory parameters and overall robot dimensions is transmitted to the electronic microcontroller and the system defines the current position of machinery relative to indicators. It is essential that the relative position (winding order) is not infringed.

Let us consider this system operation at the example. The first task for a robot before it starts operation is defining the initial area dimensions. Measuring of the area can be conducted by the following ways: 1) performing accurate motions of tractor and recording the alterations; 2) using several indicators on the tractor with the known distance between them.

The first way is marked by a significant drawback as calculating the length of the passed reference area is not an easy task due to rough and patchy land, and difference in soil resistance, also for different wheels. However in case we use internal system of distance measuring, based on e.g. accelerometer, than this drawback can be rectified. The measuring principles are similar in both cases, thus we first consider the fist way in detail and then turn to peculiarities of the second one.

Figure 1 illustrates schematically the robot displacement when defining parameters of the given area. I1-I4 – infrared tracking devices; A, B, C – tractor position; A2, B2, C2 – points located vertically lower (at the Figure) than the original points of robot position.

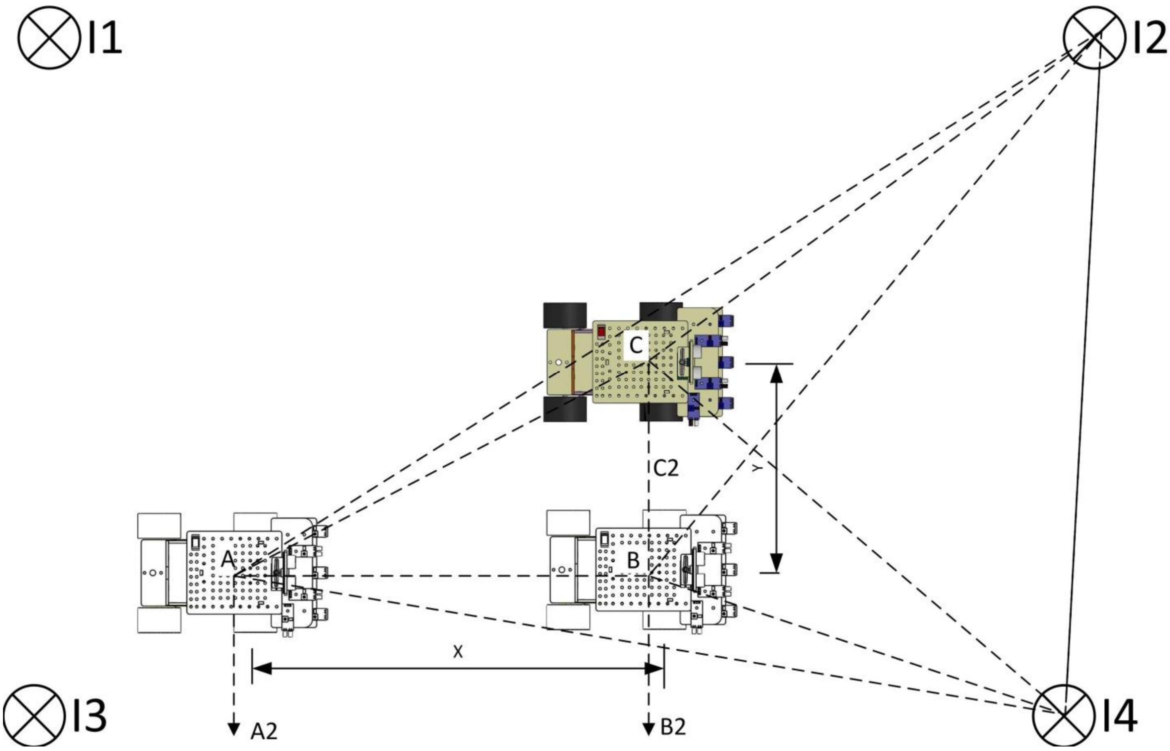

Figure 1: Robot displacement when defining parameters of a given area

Using infrared sensors robot scans 360° of space by means of servomotors (Fig. 2) to search for tracking devices. Upon finding the indicator the angle and number of the found tracking device is saved in the system memory.

At the point A we find angles A2-A-I1, A2-A-I2, A2-A-I3, A2-A-I4, than we move to the prescribed distance X to the point B, find angles B2-B-I1, B2-B-I2, B2-B-I3, B2-B-I4, at the right angle to the length A-B, after we move to point C, which is located from B at the distance Y, we find angles C2-C-I1, C2-C-I2, C2-C-I3, C2-C-I4. The obtained parameters are enough to define location of all four tracking devices regarding the tractor on the plane. Let us consider the example. We find distances C-I4 and B-I4.

Having the distance BC and two angles B_2BI_4 and C_2CI_4 , while $C_2BI_4 = 180^0 - B_2BI_4$,

We find the third angle of triangle:

$$CI_4B = 180^0 - C_2CI_4 - C_2BI_4. \quad (1)$$

Now we have the necessary values to apply standard rule for solution of triangle:

$$CI_4 = BC\frac{\sin(C_2BI_4)}{\sin(CI_4B)}; \quad (2)$$

$$BI_4 = BC\frac{\sin(C_2CI_4)}{\sin(CI_4B)}; \quad (3)$$

All the distances and missing angles required for positioning can be defined the same way.

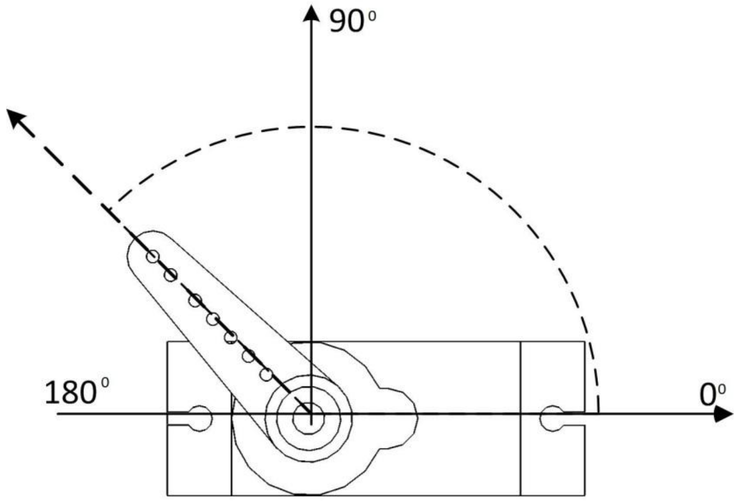

Figure 2: Operation principle of servomotor while finding the angle to tracking device

The second way can be implemented easier and faster by means of sensors placement along the angles of tractor roof. In this case the roof parameters are known, thus we only need to solve geometrical task and memorize parameters of the area (distances between tracking devices and angles), location and direction of the robot.

Two sensors mounted on servo drives with maximum turning angle 360° or four sensors with maximum turning angles 180° are enough. Sensors are fixed at the maximum possible distance within the robot body and the distance between them is considered for further calculations.

Generalized algorithm of measuring the angles between tracking devices and the robot is given in Fig. 3. Four infrared sensors with narrow field of vision in horizontal direction are used here, though other types of sensors are also possible to be used, e.g. radio position finding. Different types of sensors can be combined to control errors of random reflections. The algorithm suggests displacement of servo drive by ~0.01° each time, however it is experimental value, thus it can be changed within capacities of control circuit, servo drive resolution and area size. Each of the tracking devices generates its own original code which is known to our program. The unknown codes are rejected as invalid or interfering signals. After being launched the program should define coordinates of the robot in regards to the area and select the winding order suggesting that if some right/left side is missing than its processing has already been conducted before program restarting.

Considering that the angle of view of the sensor can be not that narrow, additional algorithm of center finding should be applied. Any other instrument can be used as a servo motor only in case its resolution capacity enables to position angles accurately on the area under study. How to control such instrument is described in details in [7].

Algorithm (Fig.3) implies accurate positioning of turning angles of servo motors with sensors that can lead to long-term waiting of process completion; however this process can be accelerated significantly by means of additional optimization.

Figure 4 illustrates a simplified algorithm of robot movement along the defined trajectory. Along with positioning system based on infrared sensors it is suggested to use electron gyroscope and accelerometer. Thus it makes possible to calculate the exact coordinates not constantly but in the definite distance intervals. The rest time, electron gyroscope is used to define turning angle while accelerometer is used to define the distance that has been passed. Magnetometer is also possible to be used. Low-cost instruments for not precise motion stabilization are also suggested for use. Systems of that kind have been considered in [8].

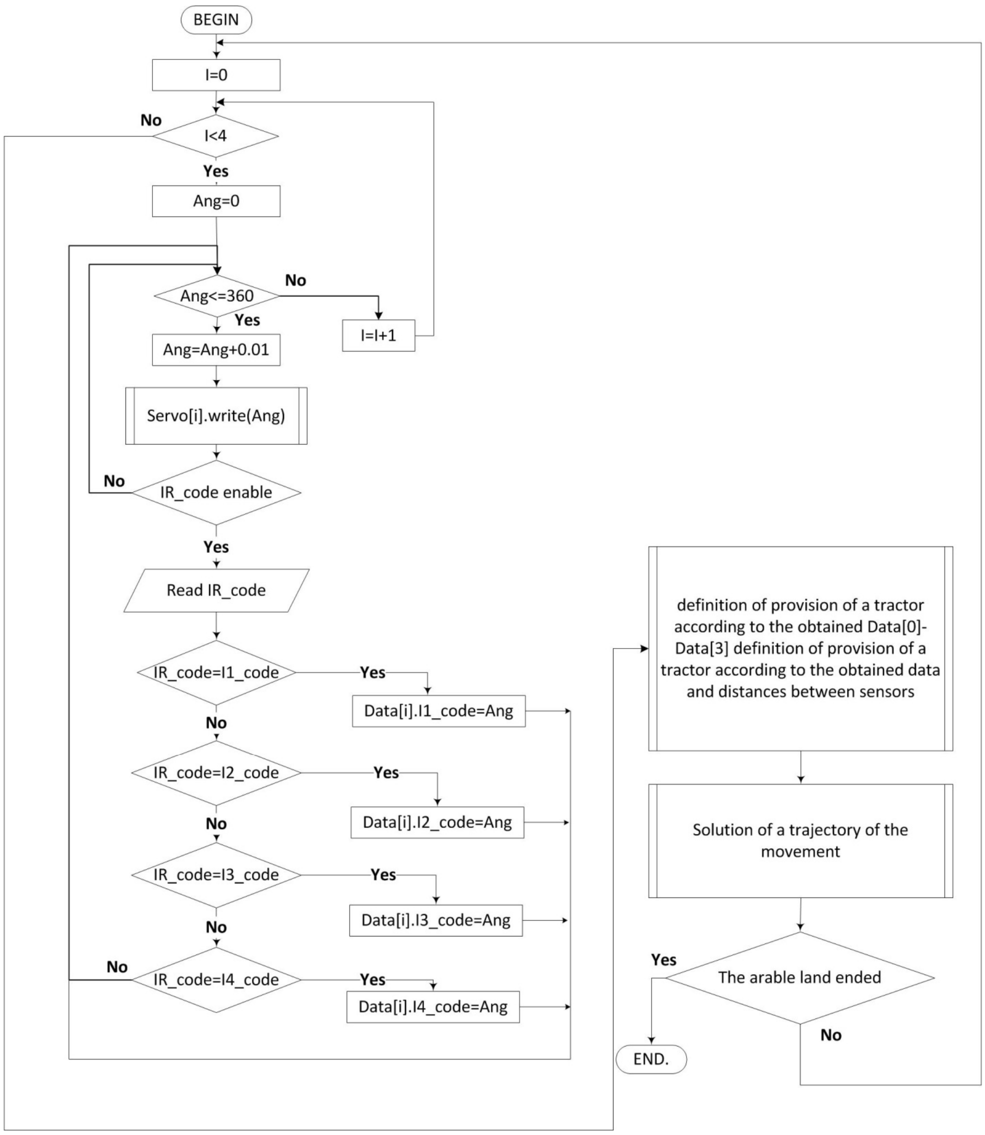

Figure 3: Generalized algorithm of angles finding for tracking devices

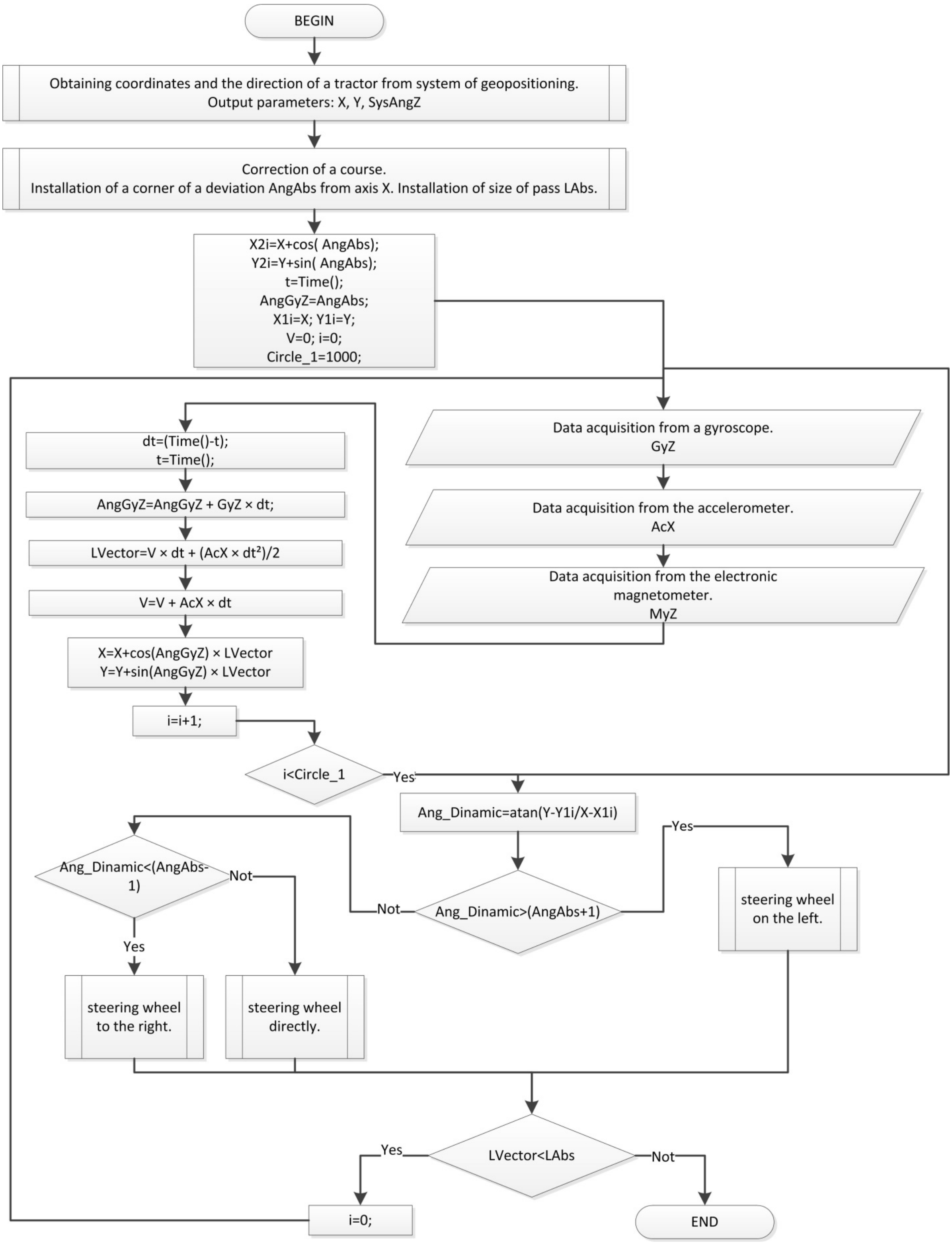

Figure 4: Simplified algorithm of robot movement along the defined trajectory

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Conclusions

Resulting from use of the above mentioned solutions the system of robot automatic positioning has been developed. It allows conducting field works without using GPS and complex systems of machinery vision. The system is low-cost and has high quality indicators. In case the mentioned system is integrated into a complex system, it is possible to develop the maximally effective structure from the point of owning cost.

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