

Low Cost GPS-Based System for Site-Specific Farming at Flat Terrains – Case Study

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ABSTRACT

Site-specific farming has been developed to the level that enables profitable use. The problem of its application in developing countries is high costs of needed equipment. The objective of research was to develop a low-cost system for application of precision farming.

The system consists of low-cost GPS receiver connected to the PLC. The test of the system applicability for local specific spraying of herbicides, following previously defined weed spots was done.

The encouraging results have been obtained. The precision of spraying could be enhanced using new generation of receivers with higher frequency rate and accuracy and including additional parameters for the PLC calculations.

Keywords: GPS, IEC 61131-3, PLC, site-specific farming

1. INTRODUCTION

After the removal of Selective Availability (SA), GPS accuracy was increased about ten times – from about 100 m to about 10 m. Using free of charge, satellite-based differential GPS systems (DGPS), e.g., EGNOS in Europe, WAAS in North America and MSAS in Asia, it is possible to achieve accuracies less than 5 m with a stand-alone unit (Rizos, 2001; Upadhyaya et al., 2005). The requirements for positioning in agriculture are specific (Sharpe et al., 2005; Gavrić and Martinov, 2006). Fields at flat terrains, like Vojvodina – Northern Province of Serbia, are the most appropriate for GPS applications, because of the good satellite visibility (Sekulić et al., 2004).

This paper describes a system which consists of GPS device that uses a free of charge, satellite-based differential GPS signal (EGNOS) and a programmable logic controller (PLC) programmed on the basis of IEC 61131-3 standard. The basic requirement set before the system is that it can be shared among several tractors. The requirements set before the PLC program are that its development and maintenance are simple and transferable to other PLC devices, it is done with the IEC 61131-3 language choice, and that it permits complex calculations using floating point arithmetic. Preliminary results have shown that this system enables the application of site specific farming on tractors equipped with implements without ISOBUS support.

Functioning of the system was tested for application of fixed amounts and concentrations of herbicides in previously identified field spots containing population of weeds.

2. MATERIALS AND METHODS

Garmin Etrex Legend, which is commercially available, was selected for use as a typical low-cost handheld GPS device (Rizos, 2001). It is capable of receiving EGNOS DGPS signal. GPS device was mounted on the top of the tractor cabin. PLC device was mounted in tractor cabin and connected, via serial cable, to the GPS device which sends NMEA messages. From the set of NMEA messages, GPRMC was selected because it contains information about all important parameters – GPS position, current speed and direction. Figure 1 shows the system in operation.



Figure 1. System at work.

The selected PLC device was EMC 320, manufactured by NEURON. It uses the programming package CoDeSys (Ver. 2.3.1.10), which supports the IEC 61131-3 standard for PLC programming. CoDeSys is manufactured by 3S-Smart Software Solutions GmbH. In this study, programming language Structured Text (ST) is used. The PLC has 16 digital inputs and 16 digital outputs with corresponding LEDs.

In this test, Amazone UF 80 sprayer was used for herbicide application. The sprayer consisted of five sprayer units controlled by PLC's digital outputs connected to sprayer unit switches on the sprayer control table – shown in figure 2.



Figure 2. Sprayer unit switches on the sprayer control table.

The activity diagram in figure 3 presents the PLC program logic. Communication, Main and Keyboard are separate segments of the program which interact through queues. LL2UTM converts coordinates from Latitude-Longitude to UTM projection.

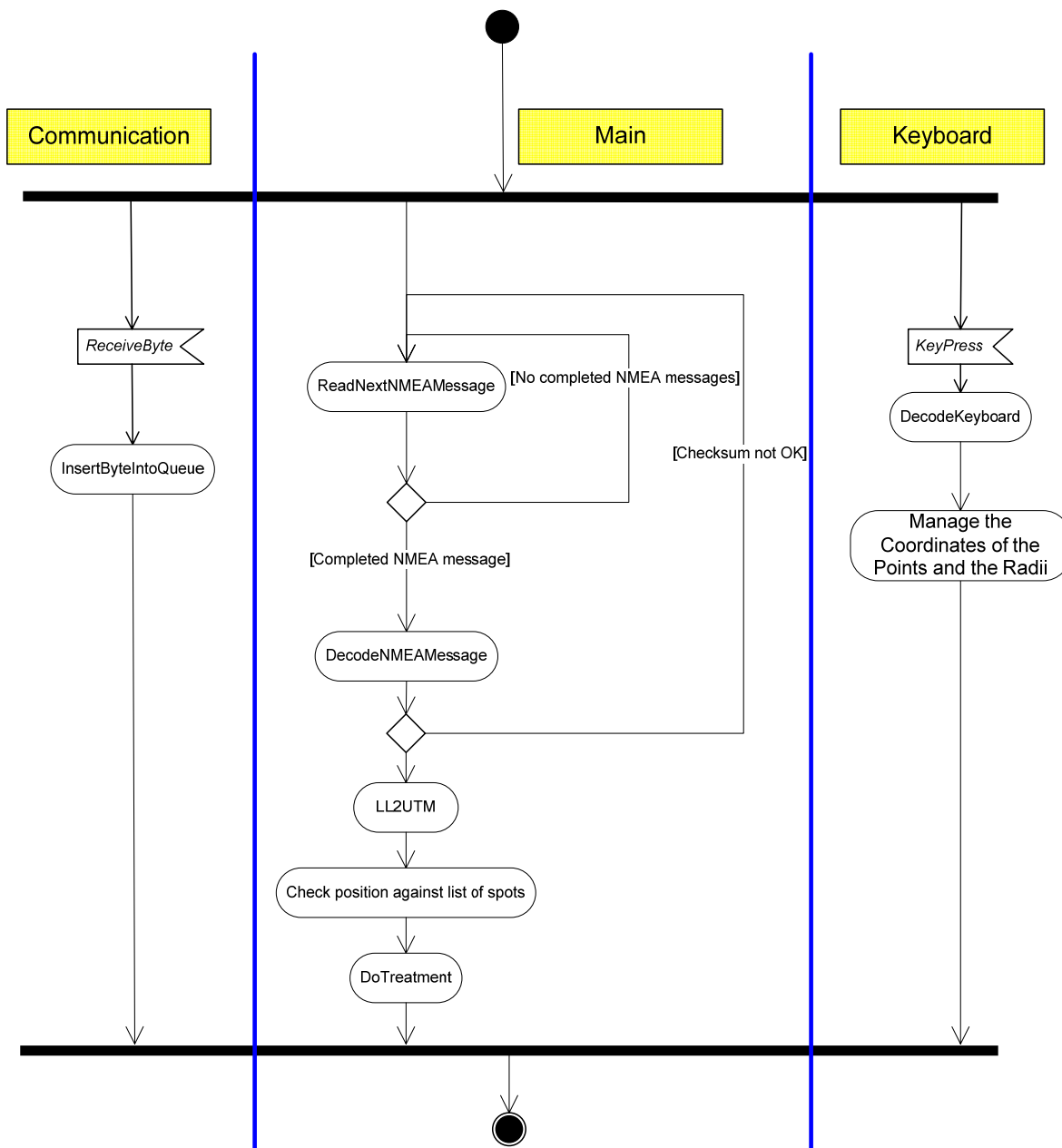


Figure 3. Activity diagram of PLC program in UML notation.

The PLC program consists of four basic parts:

- Receiving receipt for application – there are two ways of preparing the receipt. One way is to download already prepared points and radii to PLC (this could be done on the basis of aerial images or scouting with GPS device). The other way is to define points and radii using the keyboard when tractor is in the field e.g. during an earlier operation.

- Receiving NMEA message – NMEA messages received from the GPS device are entered into a queue. All messages from the queue are sequentially processed and messages different from GPRMC are discarded. After processing, a single GPRMC message is prepared for decoding.
- Decoding NMEA message – consists of two stages. The first is checksum validation and the second is decoding. If the checksum is correct then the received NMEA message is decoded. After the decoding, current position, speed, direction, time and date are further processed.
- Calculations based on current position, speed, direction, application receipt, current internal PLC state and state of its inputs – Current position data are transformed from Geographic Coordinate System (latitude-longitude format) into Projected Coordinate System (UTM format). Speed data is transformed from knots into m/s.

Position of each sprayer unit was approximated by a point placed in its middle (fig. 4). Calculation for each point was based on the sprayer unit length and the distance between the GPS device and the sprayer. The angle between the direction of tractor movement and to true north is α . Red dots are positions of the units. The points are spaced 2.5 meters apart. The distance between the GPS device and the central point of the sprayer is 3.1 meters.

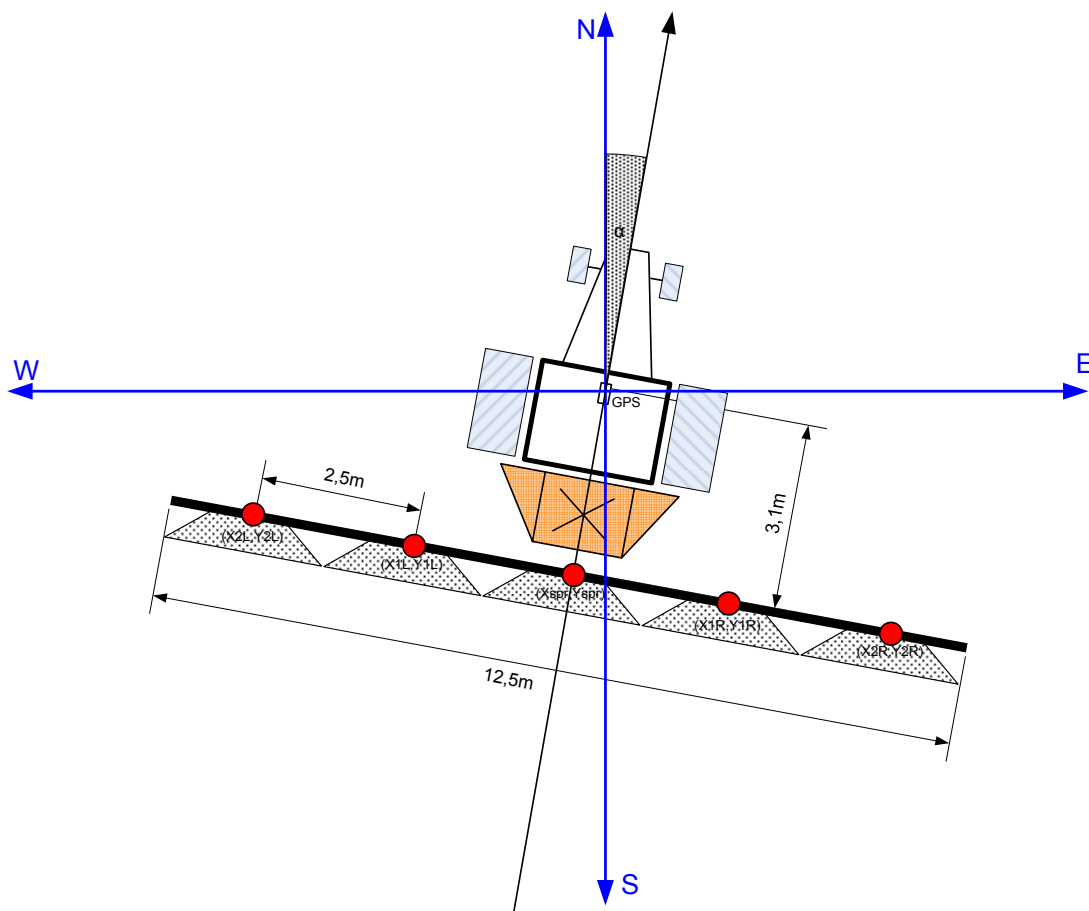


Figure 4. Scheme of tractor mounted sprayer.

For example, the calculation for the center unit of the sprayer (X_{spr} , Y_{spr}) is:

$$X_{spr} = X_{GPS} - 3.1 \cdot \sin \alpha$$

$$Y_{spr} = Y_{GPS} - 3.1 \cdot \cos \alpha$$

The calculation for the first unit to the left is:

$$X_{1L} = X_{spr} - 2.5 \cdot \cos \alpha$$

$$Y_{1L} = Y_{spr} + 2.5 \cdot \sin \alpha$$

The calculation for the second unit to the right is:

$$X_{2R} = X_{spr} - 5 \cdot \sin \alpha$$

$$Y_{2R} = Y_{spr} - 5 \cdot \cos \alpha$$

PLC controls the work of the sprayer units. Each unit is controlled by one digital output. PLC turns the units off or on depending on their calculated position. The operation of the system is shown in the figure 5. Shaded rectangles are the treated area.

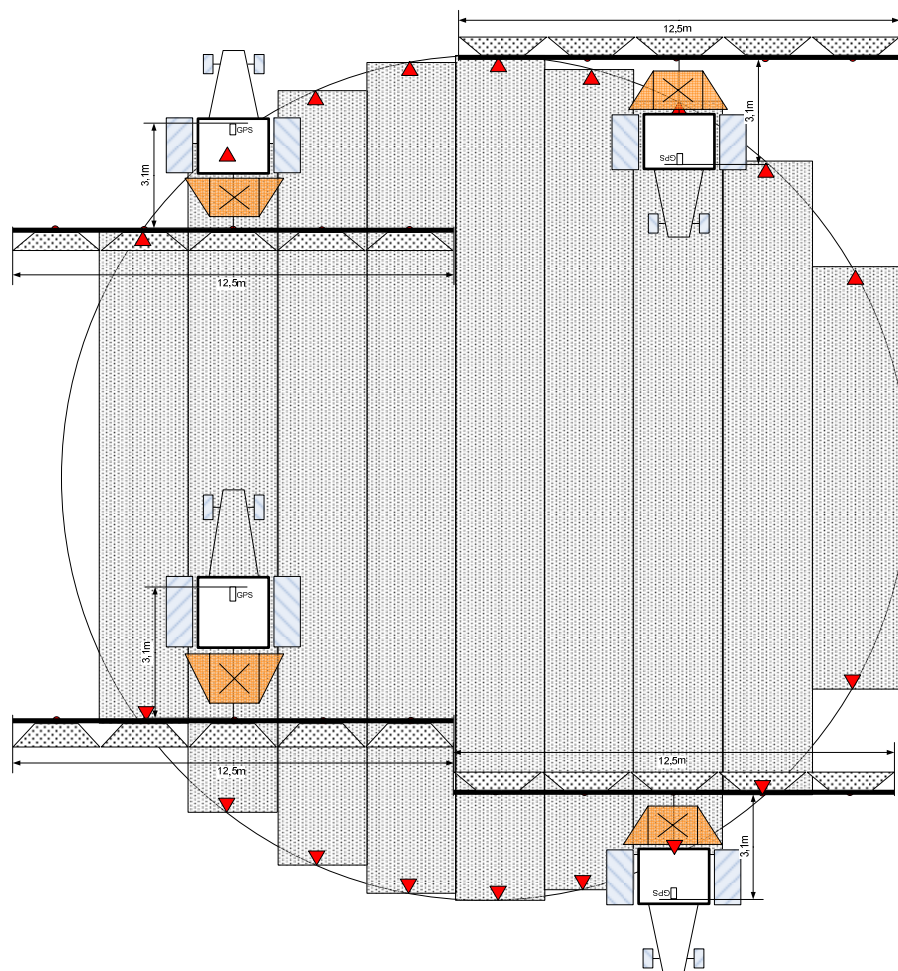


Figure 5. Start/stop spray points (red triangles).

The order of operations for the testing of the system were:

- weed scouting using the selected GPS device,
- receipt preparation,
- downloading receipt,
- online testing.

3. RESULTS AND DISCUSSION

The tests showed that the frequency of 0.5 Hz (the device sending a NMEA GPRMC message every 2 seconds) was not satisfactory. For example, at tractor speed of 10 km/h, disregarding positioning error and tractor position predicted on the basis of the received speed and direction, the maximum error is 5.55 m. Such error occurs when the message is received immediately before the tractor reaches the start/stop spray point. To reduce the error, position prediction was adjusted to simulate a GPS messaging at 1 Hz (based on the current tractor speed and direction received from GPS). In that way the maximum error was reduced to 2.78 m, at constant speed of 10 km/h. The PLC program calculates spray start/stop delay on the basis of current distance from the sprayer unit to the start/stop point and tractor speed only if the distance is less than 2.78 m (in other case there is no sense to calculate the delay because the unit will not reach the start/stop point in the next second).

Dynamic GPS accuracy is important for agricultural operations (Ehsani, 2003). Bearing in mind that the GPS device was mounted on the top of the tractor cabin, field slopes could produce significant positioning errors. Repositioning GPS device in front of the tractor could decrease the error caused by field slopes, but satellite visibility will be lower because of the tractor cabin. In practice, the error in herbicide application start/stop point was less than 1 m.

The analysis of the performed herbicide application indicated that the operation was performed with satisfactory accuracy. The developed system is also applicable in yield mapping when fitted out with a yield sensor and an additional filter for yield data. The filter serves for elimination of incorrect values or systematic errors and removal of extreme values (Lee et al., 2005).

4. CONCLUSIONS

The price of device is the basic limiting factor in new technology application in developing countries (Gavrić and Sekulić, 2004). In our case, the overall cost of the system in 2005 was 550 €. It should be mentioned here that the handheld GPS device could also be used for other purposes.

The tests were performed in a flat terrain, free of disturbances such as electrical lines, large structures, etc. The initial results obtained with the system are encouraging. The system demonstrated stability and reliability in work and high adaptability to various program changes. The satellite differential correction service provided sufficient accuracy for the performance of individual field operations such as herbicide application. Introduction of additional parameters such as wind speed and direction could improve operation accuracy.

To extend the systems capabilities, it is necessary to use a PLC with analogous inputs and outputs and a GPS device with higher accuracy and frequency rate.

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