Fruit Growing Research, vol. XXXV, 2019 DOI 10.33045/fgr.v35.2019.07
http://publications.icdp.ro/index.php

CERCETĂRI PRIVIND UTILIZAREA SENZORILOR LA APLICAREA TRATAMENTELOR FITOSANITARE ÎN LIVEZI

RESEARCH ON THE USE OF SENSORS FOR THE PHYTOSANITARY TREATMENTS APPLICATION IN ORCHARDS

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Abstract

The high precision spray application technology in orchards, depending on the geometric characteristics of the canopy, is a concept of best practices in precision agriculture. The geometrical characteristics of the canopy are closely related to plant growth and productivity and can be used to estimate harvest, required fertilizer and water consumption. During the growth period and of the life cycle, the characteristics of an orchard vary greatly depending on the vegetative stage, the support system, the variety and the density of the plants, all influencing the relationship between the amount of substance applied by the sprayer and the amount of substance that it actually reaches the target culture. The characteristics of the canopy can be measured manually or electronically. Manual measurements involve expensive and time consuming methods of sampling and data processing in the laboratory. The values obtained for the samples taken must be extrapolated to the whole plantation, without taking into account the variability in row. Electronic measurement of canopy characteristics involves the use of various types of sensors, such as ultrasound or laser sensors. The sensors mounted on the sprayer provide real-time information on the characteristics of the target crop, information that is processed by a computer and used for spray control.

Cuvinte cheie: senzori, tratamente fitosanitare, agricultură de precizie, livezi.
Key words: sensors, phytosanitary treatments, precision agriculture, orchards.

1. Introduction

Due to the ever-changing characteristics of an orchard during the growing period and the life cycle, the maps required for applying variable rate need to be updated frequently, which makes map-based technology very expensive. Within the sensor-based technology, technology developed within the project *PN-III-P1-1.2-PCCDI-2017-0662 - Increasing the institutional capacity of research - development-innovation in the field of ecological fruit growing*, the laser sensor mounted on the spray equipment provides real-time information on the characteristics of the target crop, information that is processed by a programmable controller and used for spray control.

The characteristics of the canopy can be measured manually or electronically. Manual measurements involve expensive and time consuming methods of sampling and data processing in the laboratory. The values obtained for the samples taken must be extrapolated to the whole plantation, without taking into account the variability in row.

Electronic measurement of canopy dimensions in orchards has been studied over time by several researchers (Escolà, 2011; Zaman, 2004; Balsari, 1998). Giles et al. (1987) developed a system based on ultrasonic sensors placed at different heights on the spray equipment, for measuring the volume of the canopy, in peach and apple orchards. This system was subsequently improved by the same authors (Giles et al., 1989), by using an advanced control algorithm, the results leading to a pesticide economy of up to 52%. However, due to the relatively large divergent angle of the ultrasonic waves, the target area becomes larger as the distance between the sensor and the target increases, reducing the accuracy of the measurements and increasing the possibility of signal interference between two adjacent sensors (Wei and Salyani, 2004).Schumann and Zaman (2005) developed a software running under Windows to analyze and process the data collected by ultrasonic sensors to measure the height and volume of the crowns, with high accuracy, at a rate of about 13.6 trees per minute.

More recently, Balsari et al. (2008) designed and built a sprayer prototype capable of automatically adjusting the amount of liquid and the volume of air distributed depending on the characteristics of the target, the health of the crop (water stress, diseases and pests) and environmental conditions (eg. wind speed and direction).

The objective of the present paper is to develop an automatic system for detecting the canopy characteristics, in order to apply phytosanitary treatments with high precision in orchards.

2. Material and methods

The automatic system for detecting the target characteristics, realized by INMA Bucharest within the project *PN-III-P1-1.2-PCCDI-2017-0662 - Increasing the institutional capacity of research - development-innovation in the field of ecological fruit growing,* was implemented on an orchard sprayer (fig. 1), whose characteristics are presented in table 1.

The automatic system mainly consists of: laser sensor model SICK LMS111-10100; control box; two proportional solenoid valves; support for adjusting the position of the laser sensor. The main technical characteristics of the laser sensor are presented in table 2.

The laser sensor position adjustment bracket (Fig. 2) is a welded rectangular construction mounted on the sprayer frame. It consists of a vertical arm *1*, a cross *2* and a horizontal arm *3* which has at the end welded the plate *4*. The sensor is fixed to the plate *4* by means of parts *5* and *6* in U shape. On the two arms are drilled at equal distances where the locking bolts *7* come in. The position of the sensor can be adjusted in the following directions:

- horizontally (front - back), by sliding the arm *3* in the slide *2*;
- vertically (up-down) by moving the slide *2* on the arm *1*;
- in a vertical plane (angular adjustment), by rotating the sensor together with the part *5* with respect to the part *6* provided with an elongated hole.

The scanning range of the LMS 111-10100 is dependent on the remission of the objects to be detected (Fig. 3). The better a surface reflects the incident radiation, the greater the scanning range of the LMS. With increasing distance from the LMS the laser beam increases in size. As a result the diameter of the measured point on the surface of the object increases. The distance-dependent diameter of the measured point is the distance (mm (in)) × 0.015 rad + 8 mm (Fig. 4).

The distance between the measured points is also dependent on the angular resolution configured. With a coarser resolution, the distance is larger with a finer resolution the distance is smaller. The distance-dependent spacing between the measured points is the tangent of the angular resolution × distance (Fig. 5).

The beam diameter is always greater than the measured point spacing. As a result full scanning without gaps is ensured. To reliably detect an object, a laser beam must be fully incident on it once. If the beam is partially incident, less energy will be reflected by an object than necessary in some circumstances. How to calculate the minimum object size: beam diameter + distance between the measured points = minimum object size

SOPAS ET configuration software. The interactive configuration is carried out using SOPAS ET. Using this configuration software, you can configure and test the measurement properties, the analysis behavior and the output properties of the system as required. The configuration data can be saved as a parameter set (project file) on the PC and archived.

The LMS is adapted to the local measurement or detection situation using SOPAS ET. For this purpose a custom parameter set is created using SOPAS ET. The parameter set can either be loaded initially from the device (upload) or it can be prepared independently. The parameter set is then loaded into the LMS. This action is performed either immediately (SOPAS ET option IMMEDIATE DOWNLOAD) or manually (SOPAS ET command DOWNLOAD ALL PARAMETERS TO THE DEVICE).

For the measured value output, the LMS supplies measured values to one of the interfaces. It is prerequisite for this data output that the LMS is in the measurement mode. There are two ways to start the measurement mode:

➢ start via SOPAS ET

PROJECT TREE, LMS…, PARAMETER, BASIC PARAMETERS, area MEASUREMENT;

➢ start via telegram.

After the measurement mode is started the LMS needs a little time to reach the status “Ready for measurement”. Should therefore query the status of the LMS using the sRN STlms telegram. Then request measured data by using a telegram on the interface from which want to receive measured data. There are two possible ways of doing this:

➢ Exactly one measured value telegram can be requested using the sRN LMDscandata telegram — the last scan measured is transferred;

➢ Measured data can be continuously requested using the sEN LMDscandata telegram — measured data are then transferred until the measured value output is stopped using the sEN LMDscandata telegram.

The LMS is adapted to the evaluation situation with the aid of up to ten evaluation cases (type-dependent). In the evaluation case, one of max. ten configurable evaluation fields, an evaluation strategy, an output and in some circumstances a combination of inputs that activate the evaluation case, are selected. An operator is selected for each output; this operator determines the result on the output if more than one evaluation case acts on the output (Fig. 6).

3. Results and discussions

Step 1: Commissioning of the laser sensor for measuring of canopy contour between two rows in an apple orchard (Fig. 7). The SOPAS ET software was installed on a laptop and the laser sensor was set up to output continuously the measured data, with the following features: scanning frequency 50 Hz and angular resolution 0.5°.

The number of data point outputted for each scan was 540 (full range 270°x angular resolution 0.5°). In figure 8 is presented a sequence of measurement viewed on the SOPAS ET software interface.

On the bottom of the image we can observe de soil line. On the left and right side of the LMS we can observe clusters of points which represent the foliage and branches of the trees. Each point contains information about the distance between the LMS current position and the measured point. The current reference system that the data is transmitted is in polar coordinates (because we know the distance and from the point position in the vector of distances, we can compute the angle) and could easily be transformed in orthogonal coordinates in order to calculate the contour (as in current image).

The data was arranged in vectors of 540 values which were latter split up in two equal areas of interest corresponding to left and right rows of trees. Further on we transformed from polar coordinates to cartesian coordinates and we eliminated values which were associated to soil surface by defining the minimum and maximum height of the trees.

The variations in canopy width for half of the row measured by LMS at different heights between minimum and maximum height using following equation:

$$G_i = {}^{d}/_{2} - x_i \quad (1)$$

where: G_i is the canopy thickness (m), for half a row at height *i*; d - the distance between the rows of trees (m); x_i - the distance measured from the sensor axis to the outside of the crown (m), to the height *i.*

For this calculation it was considered that the position of the sensor relative to the axes of the rows of trees is kept constant during the movement. Because the scan frequency was set to 50 Hz, for an average travel speed of 1.4 m/s, a length *l = 0.028* cm from the canopy (in the row direction) was scanned. This value was then used to estimate the volume of the canopyto be sprayed on each measurement. Therefore, the flow rate of substance *Qi* was determined using the formula (2):

$$Q_i = 60 \times G_i \times H \times l \times f \times c \text{ (l/min)} \quad (2)$$

where: G_i is the canopy thickness (m), for half a row at height *i*, calculated with formula (1); *H* - canopy height (m); *l* - the scanned length, depending on the scan frequency (*l = 0.028 cm*); *f* - scanning frequency *(f = 50 Hz*); *c* - application coefficient (*c = 0.095* l / m^3).

The flow rate value calculated by formula (2) will be converted into an electrical signal transmitted to the proportional solenoid valves. The conversion of the flow rate value into an electrical signal will be carried out in accordance with the calibration curve that will be obtained experimentally.

Step 2. In our project we developed an communication interface in LabView software, using the Ethernet communication port, in order to be able to collect the measured data for each scan using telegram command language provided by Sick.

The program created in LabView for spraying control consists in two tasks:

- Ethernet communication task between LMS and programmable controller (Fig. 10);
- Task of data processing and manual / automatic control of solenoid valves (Fig. 11).

On each boom (left / right) you can automatic control of the spraying operation. Within this task is implemented the mathematical model for calculating the variable flow rate based on the average distance until the canopy measured by LMS, in real time. Thus, the distance vector received by LMS communication converts into two distance vectors for the left / right boom. By mathematical calculation the polar coordinates are transformed into cartesian coordinates; then for each side the minimum and maximum height of the canopy is identified and the average distance to the canopy is calculated based on these extreme points. Based on the distance calculation, the left / right variable flow rate will then be calculated and then the control voltage of the proportional valves depending on the reference flow rate imposed for each side. The figure 11 shows the variable evolution of the flow rates over time at a given moment. It can be seen that the system also allows different reference flow rates for left / right side.

4. Conclusions

In this paper, using the field evaluation feature of the laser sensor, we constructed two evaluation fields corresponding to the area of the two tree rows that will be sprayed.

Two digital outputs were used for controlling the two valves corresponding to the left and right boom with nozzles. Their control was performed in function of the characteristics of the trees so that a variable spraying uniformity will be obtained.

The major advantage of this type of control is reduction with 30÷35% of substances waste because of spraying the gaps between the trees. Another advantage is the increased precision compared with the ultrasonic similar sensors which are usually influenced by each other because the ultrasonic waves are reflected randomly bay the trees leaves.

Acknowledgements

This work was supported by a grant of the Romanian Ministry of Research and Innovation CCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0662, *Increasing the institutional capacity of research - development-innovation in the field of ecological fruit growing*, Contract no.12 PCCDI/2018, within PNCDI III.

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Tables and figures

Table 1. The main technical characteristics of the orchard sprayer

Tank capacity	300 l
Fan	with axial absorption and radial air discharge
Number of nozzles	12, mounted symmetrically left - right on 2 stainless steel ramps
Pump model	Imovilli M50
Maximum flow	48 l/min
Maximum pressure	40 bar
Pressure regulator	two ways

Table 2. The main technical characteristics of the laser sensor

Model	LMS111-10100
Aperture angle	270°
Scanning frequency	25 / 50 Hz
Angular resolution	0,5°
Working range	0,5 ... 20 m
Enclosure rating	IP 67
Light source infrared	905 nm
Supply voltage	10,8 ... 30 V cc
Response time	≥ 20 ms
Power consumption	8 W
Electrical connection	4 xM12 plug-in
Communication protocol	RS-232

Fig. 1. The automatic system for detecting the target characteristics (item 1), implemented on the orchards sprayer (item 2)

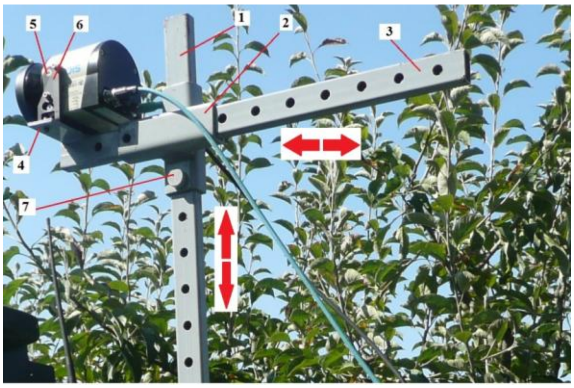

Fig. 2. The laser sensor position adjustment bracket

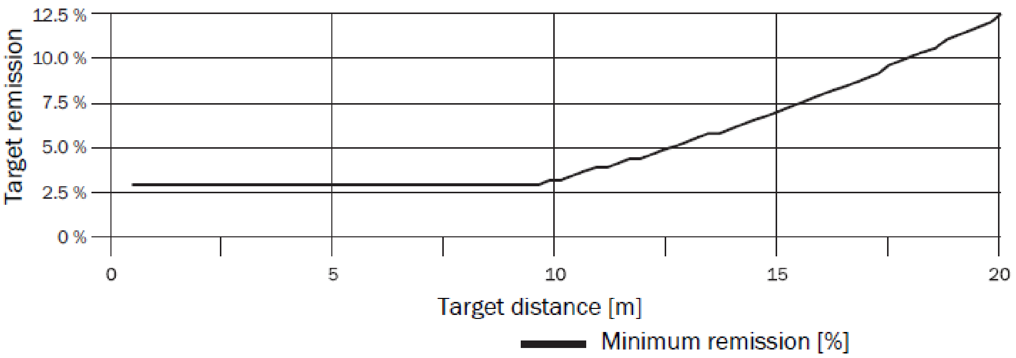

Fig. 3. Scanning range as a function of the target remission (SICK AG, 2017)

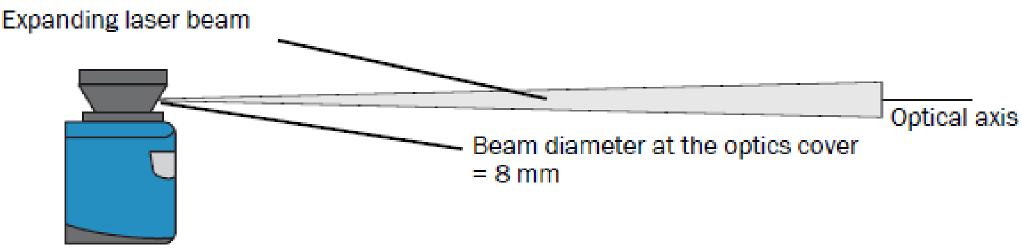

Fig. 4. Beam expansion

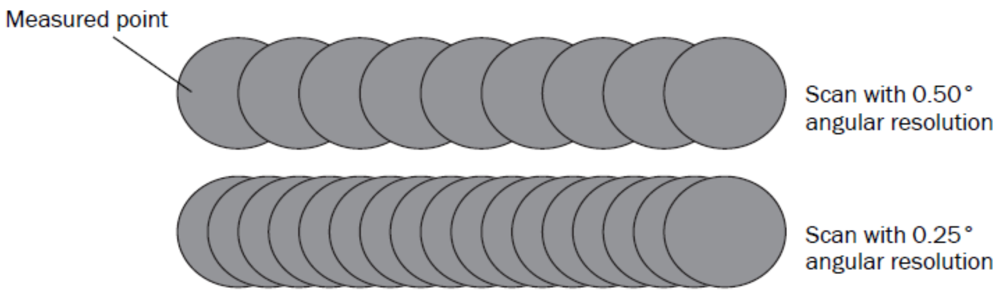

Fig. 5. Schematic layout of the distance between measured points at different angular resolutions (SICK AG, 2017)

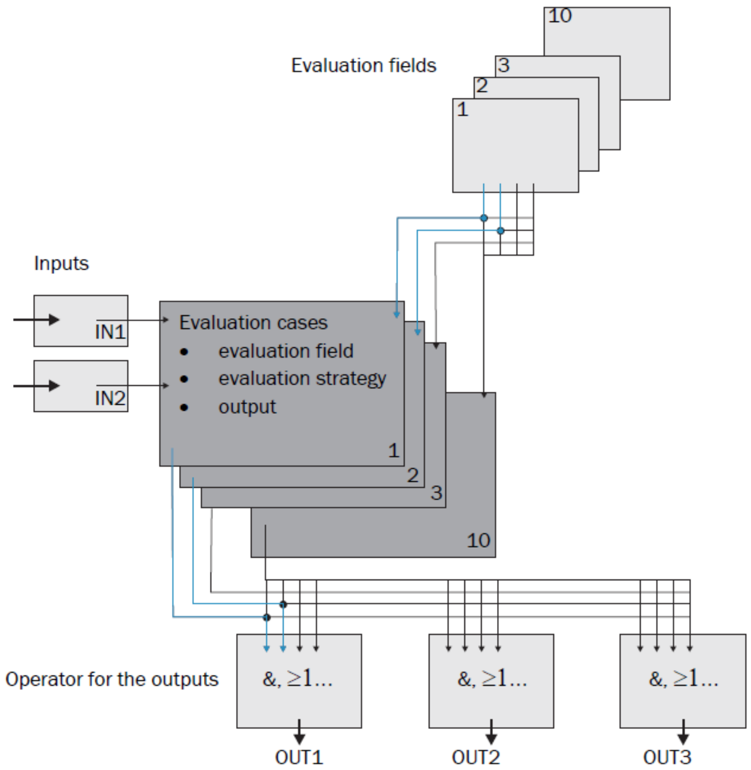

Fig. 6. Principle of the field application (SICK AG, 2017)

Fig. 7. Commissioning of the laser sensor for measuring of canopy contour

DOI 10.33045/fgr.v35.2019.07

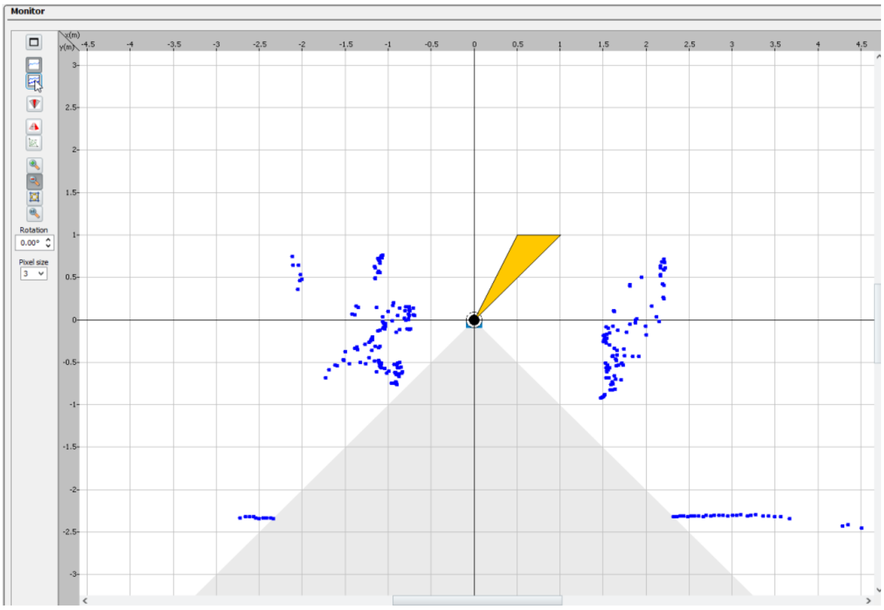

Fig. 8. Measuring sequence (interface of SOPAS ET software)

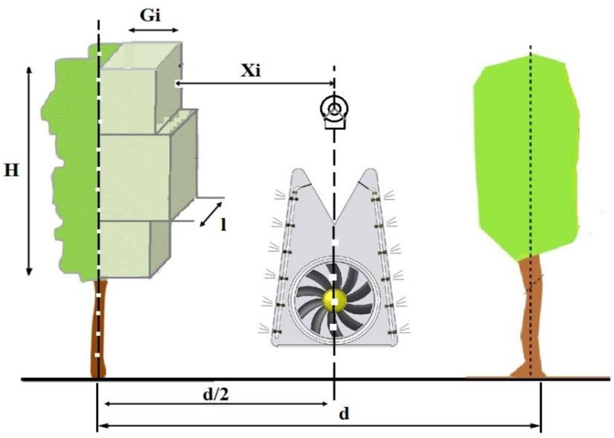

Fig. 9. Geometrical characteristics of the canopy taken into account

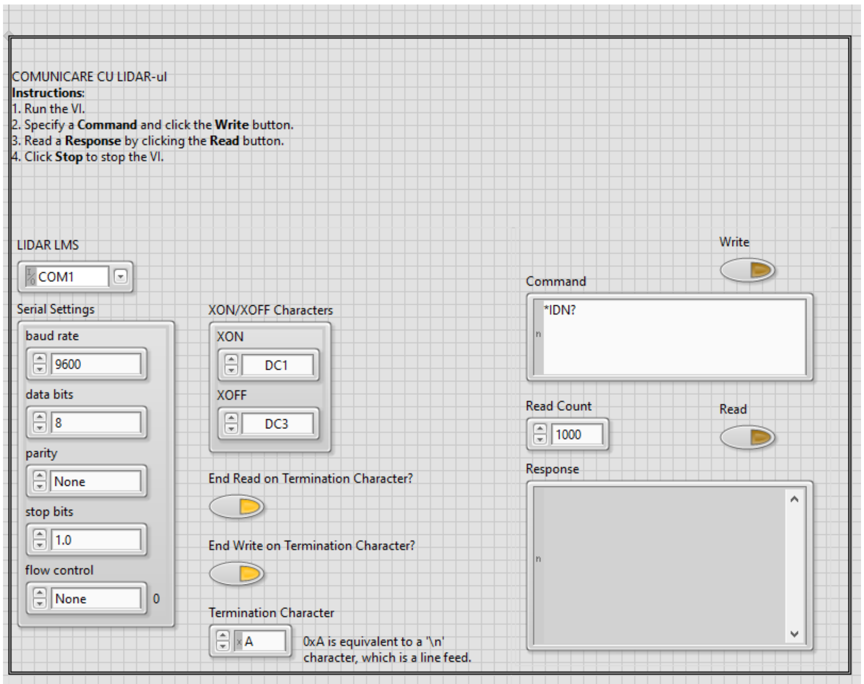

Fig. 10. Graphical interface task Ethernet communication between LMS and controller

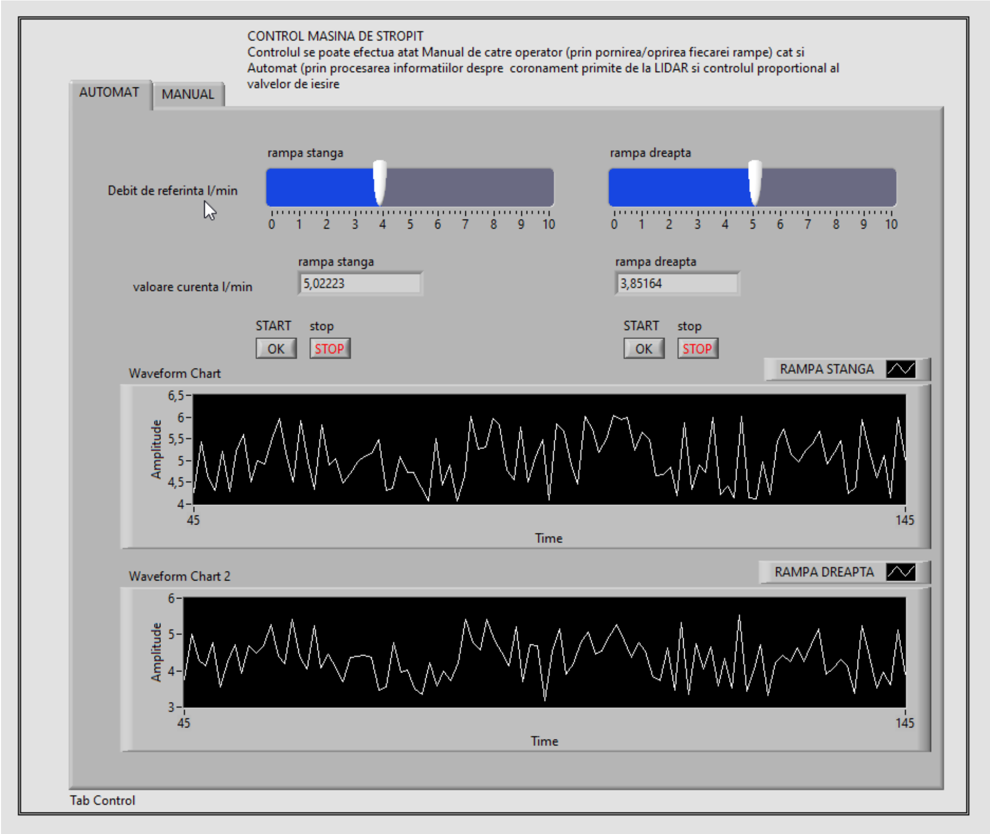

Fig. 11. Graphical interface of automatically task control