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The Program Complex of Operational Monitoring of Agricultural Machinery Work with the Use of High-Precision Positioning Systems

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Annotation

The paper describes the monitoring system for agricultural machinery. The purpose for the development of the system is to control the harvesting and delivering grain to the elevator. The system implementation requires the additional equipment installation on the machinery that provides: coordinating the object with high accuracy, determining the moments of mutual approach and the moments of on / off mechanisms of grain unloading. Monitoring the harvesting is carried out in real time.

Keywords: Harvester monitoring system, grain control, hight-precision positioning systems

INTRODUCTION

Currently, energy and resource-saving technologies are used in all the fields of human activity. The system of precision farming is one of the basic elements of this technology in agriculture. The concept of precision farming is based on managing the productivity of agricultural lands, taking into account the inhomogeneity of agroclimatic parameters within the field. Accumulated at the moment, foreign experience shows that the proposed approach makes it possible to increase the reproduction of soil fertility and the degree of ecological purity of the products that, of course, affects the reduction of costs and provides an economic effect.

The implementation of the accurate farming concept, primarily based on the automation of seeding, harvesting and storage of crops, which is achieved through the use of robotic systems, as well as various monitoring systems. The first place in the use of precision farming systems is occupied by farmers, growing corn and soybeans, the second place is occupied by farmers, growing wheat. Almost all of the implemented technologies use operational, coordinate information about the state of agricultural machinery on the field, which is achieved through the use of high-precision navigation systems. So in Australia, a high-precision network is created, based on Trimble base stations, which is the first VRS network with GNSS signal reception.

The second step to automation is the installation of various sensors on the equipment that provide logging the operation modes of the equipment and the state of its main nodes with the purpose of further analysis and cost reduction, the automation of some type of work.

The article describes the developed program complex for monitoring the operation of agricultural machinery, using high-precision positioning systems, and reveals the list of equipment used and the tasks to be solved.

RELATED WORK

The development of monitoring systems in agriculture has been done for the past 20 years. As trends in their development, it is possible to identify areas for improving networks and communications, sensors for primary information and automotion.

In works [1], [2] the monitoring system included Web servers and sensors placed in orchards to collect visual, temperature and humidity information via wi-fi. Connecting Web servers to the Internet allowed for continuous monitoring, control of agricultural operations and made fruit cultivation open. In work [3] different ways of data transfer, wi-fi devices and their configurations in the network are analyzed, providing minimum power consumption and fast transfer from field data to the Web server.

Sensor improvement technologies are presented, for example, in work [4], where on the ARM board there is a large number of sensors installed, which collect information on temperature, humidity, water level, salt in the soil. In case of critical values, the farmer's notification is carried out via SMS message to the phone. Work [5] describes the experiment on the installation of sensors for various purposes on the harvester and the connection of equipment to the laptop, for the purpose of recording and analyzing information to increase its productivity and reduce losses.

A modern trend in the development of agriculture is the extension of the concept of precision farming to large farms, where the main goal is the effective management of various agricultural machinery integrated into a single network. As a rule, the network has a single control center for harvesting equipment (CCHE) providing monitoring of harvesting, monitoring grain movement to the elevator and calculating the efficiency of agricultural processes. The article gives an example of an online service that provides a solution to a number of tasks designed to improve the efficiency of agricultural work.

Description of hardware-software complex

The program complex of operational monitoring of agricultural machinery is designed to solve the following tasks:

- Obtaining operational information for decision-making;
- Increasing the efficiency of using agricultural machinery;
- Improving the quality and reliability of information on the progress of field work;
- Minimizing the influence of the human factor in the system of information collection during field work;
- Reducing non-production losses (grains, GSM, etc.).

The operating principle of the hardware-software complex (HSC) is to obtain the information about the status and location of agricultural machinery in the harvesting process, to transfer this information to the CCHE and to carry out software calculations, the result of which is obtaining statistical data on the progress of work in the online mode (figure 1).

Figure 1: Online monitoring system window

During the harvesting and storage of the crop, the following objects are involved (figure 2):

- Harvester;

- storage bunker;

- truck;

- tractor (for transportation of storage bunker);

- elevator;

- the control center for harvesting equipment (CCHE).

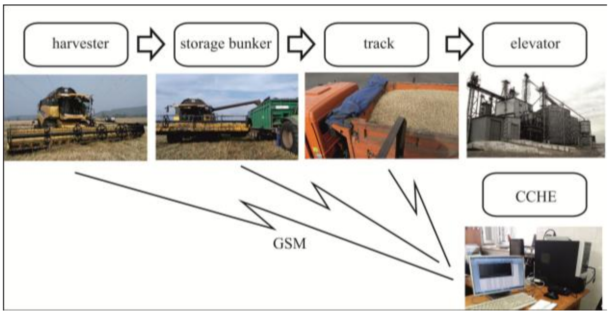

Figure 2. Description of the monitoring system for agricultural machinery

The harvester performs harvesting from the field and, after filling up its bunker, unloads into a storage bunker or truck.

The storage bunker serves for temporary storage of collected grain and its subsequent transfer to a truck. The storage bunker is a container, mounted on a trolley and equipped with an unloading auger.

The truck is designed to transport harvested grain from the field to the elevator. Loading of the truck by grain can be carried out both from the combine harvester and from the storage bunker.

The tractor is designed for transportation of storage bunker.

Elevator is designed for receiving grain and its storage.

The control center for harvesting equipment includes an automated workplace on which the database is stored, and software calculations are carried out.

The following equipment is installed at the facilities (figure 3):

- The combine harvester, equipped with end grain level sensors in the bunker, sensors for extension and operation of the auger mechanism, a RFID reader, a GPS receiver, an accelerometer and a GSM transmitter for sending sensor states to the CCHE server;

- The storage bunker is equipped with a weight measuring platform (based on load cells), RFID tags, a RFID reader, a sensor for extension of the auger mechanism , a GPS receiver, an accelerometer and a GSM transmitter for sending sensor states to the CCHE server;

- The truck is equipped with RFID tags, two angle sensors for measuring the angle of truck body deflection from the frame, a GPS receiver, an accelerometer and a GSM transmitter for sending sensor conditions to the CCHE server;

- The elevator is equipped with a weight measuring platform installed at the entrance to monitor the weight of the truck before and after unloading, equipped with ultrasonic distance sensors for detecting the entrance to the platform of truck scales, and RFID-readers for identifying the truck on the platform.

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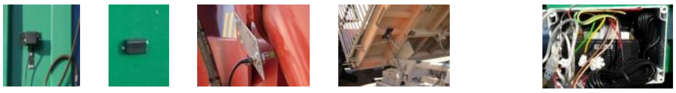

a b c d e

Figure 3: Examples of equipment (a - RFID reader, b - RFID tag, c - auger extension sensor, d - body lift sensor, e - electronic recorder «Autograph» and GSM module)

Solution of the task of continuous monitoring of agricultural machinery

To solve the problem of continuous monitoring, based on telemetric information from sensors, it is necessary:

- Identify the participants in the production chain: combine harvester -> storage bunker -> truck -> elevator.
- Calculate the mass of the unloaded grain mixture between the objects, calculate the harvest statistics for further analysis of the efficiency of the production process, identify the cases of the grain mixture theft, the facts of inefficient use of the harvesting equipment or the use of the harvesting equipment for personal purposes.

The complexity of the solution of the problem is determined by the following factors:

- Insufficient coverage of the GSM signal reception area in the field of agricultural work;
- Asynchronous data transfer from the harvesting machinery equipped with sensors;
- Problems with the identification of the harvesting equipment in the case of their close location, for example, which of the two nearby trucks loaded a grain mixture into the storage bunker (figure 4);

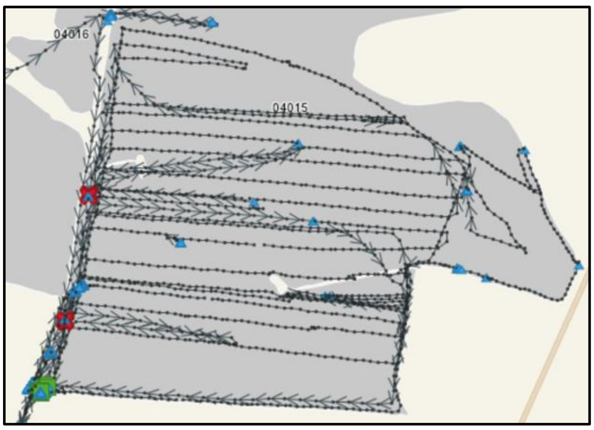

Figure 4: Fragment of the window of the program complex with trajectories of agricultural machinery movement (blue triangle - truck, green square - storage bunker, red circle - harvester)

The data from the sensors have a time stamp (the time stamp is determined on the basis of the GPS / GLONASS technology from the corresponding receiver) and transmitted to the server via the 2G mobile network as it is available. If at the time of receiving the data from the sensor the data can not be transmitted to the server because of the absence of connection, the data is stored in a protected ROM. When the connection with the server is established, the data from the ROM is unloaded to the server in chronological order. The ROM capacities are enough for a weekly amount of data.

It is convenient to represent the production chain in the form of a graph whose vertices are the events of unloading from one object to another, the edges of the graph represent a connection between the unloading events. First of all, it is necessary to distinguish the criteria for identifying the unloading events based on the on-board equipment installed on each type of harvesting equipment:

- for the combine and the storage bunker, the main criterion for identifying the unloading event is the readings of the auger speed sensors;
- for the truck, it is the angle of the body lift, exceeding the threshold of the permissible value of 20 degrees.

The identification of the unloading events takes place on the CCHE server at the time of the completion of the event and the arrival of the event ending sign to the CCHE. The key indicator for the unloading event is its time range.

To determine the proximity of the harvesting machines, RFID tag data is used. Active tags are used for the harvesting machines. The technology of identification by RFID tags works as follows: the closer the tag is to the RFID reader, the more frequently the device registers its identifier. The reader is installed on the hull of the harvesting equipment in close proximity to the auger in the direction of its extension. As a result, it is possible to calculate the probability of correct identification of the recipient for each unit of the equipment.

Sometimes this method of identification is erroneous. For example, in the case when the unloading takes place in one car, and the second one, equipped with a tag, passes by. To avoid identification errors, the server also analyzes the average distance between the donor and the recipient, based on the coordinate information from the GPS receivers, after the corresponding geodetic transformation from the global coordinates to the local coordinates. Thus, the average distance to the donor during unloading corresponds to each potential recipient, in addition to the probability of identification by RFID. In addition, checking the GPS coordinates of the recipient helps to avoid theft of grain by using a tag removed from the car. Such cases are registered by the algorithm, and the identifier of the tag is marked as unresolved and the information about the suspicious event is transmitted to the operator of the CCHE.

For the combine, the level of the grain mixture in the bunker at the moment of the start and end of the unloading is also attached to the unloading event; and for the storage bunker, the same figure is the grain mixture mass.

A wide range of sensors allows an operator to divide the unloading events into authorized, unresolved and requiring the operator's verification. In the event that the probability of identification is low, such events require the CCHE operator's verification. The events with an undefined recipient refer to the unauthorized ones and require special attention of the operator.

Unloading from the combine into the storage bunker and unloading from the storage bunker to the truck allows to measure the weight of the loaded / unloaded grain mixture, which is also calculated in the CCHE. This is necessary for tracking the mass of grain during transportation.

The truck unloading events are divided into authorized and unauthorized. The authorized unloading events are considered those ones, occurred on the territory of the elevator, and along with this, the mass of grain, received at the elevator, should be no less than the mass, loaded from the storage bunker into the truck on the field. Attaching the unloading to the elevator is performed by the GPS coordinates of the truck and the position of the elevator on the map. At the entrance to the elevator there are platform scales mounted and connected to the computer, which measure the weight of a full and empty truck. The truck is identified by RFID technology.

The identification of the unloading event for each type of the machines occurs independently. The result is a one-way donor-recipient chain. Then the unloading events are combined in time in reverse recipient->donor order, which allows to create the table of related events, according to which it is easy to calculate the mass of grain that the truck was supposed to deliver to the elevator and to track suspicious events.

Thus, at the time of unloading the truck at the elevator, the operator is able to view the entire chain, associated with this unloading of the events. In addition to the unloading events, the CCHE records stops and downtime of the equipment, according to the accelerometer readings, and the time for simulating the unloading on the field, according to the auger extension sensors. All this information is displayed in the CCHE in arbitrary time intervals, customizable by the operator, which allows to analyze both the summary statistics and the detail.

Ways to reduce non-production losses, realized in the project

We will count losses, associated with loss of grain and fuel and lubricants, as non-production ones.

We will distinguish the following stages of grain delivery from the field to the elevator:

- grain harvesting by a combine harvester on the field;
- loading of grain into a truck or storage bunker;
- grain unloading into the elevator.

At the grain harvesting stage, there are direct and indirect losses, directly connected with the combine. In this case, direct loss of grain means losses connected with the direct leaving of grain on the field, and indirect loss of grain means damage, grain crushing, as well as the presence of impurities. Direct and indirect losses of grain by the combine are characterized by losses relating to losses at the combine components: a grain platform, a conveyor, a separator, a blower, etc. Reducing direct losses is described in work [6]. Reducing indirect losses is directly related to the installation of an additional camera on the combine, in order to analyze the grain quality and to determine the impurities [7],[8].

At the stage of loading grain into a truck or a storage bunker, the loss of fuel and lubricants is directly related to the expectation of a truck (a simple combine) arrival as well as grain losses, resulting from loading grain into the body, due to the inadequacy of the auger position [9].

The losses, connected with unloading grain into the elevator are related to the non-optimality of the truck's route to the elevator and its downtime. Grain losses here, as a rule, are not observed. The situations with grain scattering due to the truck movement are solved by covering the body with a tent. The facts of grain theft are determined by taking into account the mass of the grain, unloaded by the combine at each stage of its movement and reception at the elevator.

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