To the question of creating a device for cleaning and sorting of grain

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Abstract. Currently, various technical devices for cleaning and sorting grain material are being developed intensively, which use new innovative technical vision devices. The use of technical vision devices makes it possible to more effectively separate the main grain from various impurities, including difficult-to-separate impurities. The development of such technical devices largely depends on the calibration of the digital vision system, and this affects the correctness and accuracy of reading the main particle sizes of grain material. Knowing the location of the intersection of the surface under study with the optical line of the camera’s photo lens, it is possible to configure the camera. To set up the technical vision system, it is necessary to determine the external and internal technical characteristics of digital cameras. We have proposed a system for changing the focal position of the camera’s photo lens to determine the intersection of the optical axis of the camera’s lenses with the working surface of the device.

1. Introduction
Post-harvest grain processing, its sorting and cleaning are the most important operations in grain production. But currently most of grain processing equipment of small farms has a large degree of wear and tear and do not meet the growing demands for the quality of grain material processing. In this regard, it became necessary to design a new highly efficient high-tech equipment based on advanced technologies.

Advanced technologies are presented by a device for cleaning and sorting grain [1] capable of processing an extensive list of agricultural crops from leguminous and oilseed raw materials to universally grown wheat, rye, barley and oats.

The grain processing device [1,2,3] can perform measuring and fixing the geometric dimensions of particles of grain material in a short period of time, almost instantly, as well as finding grain defects and identifying the color of the particles. The device determines and fixes such geometric dimensions as thickness, width, length and shape of grain material particles [5,6,7]. The visual system of the device receives information of the visible part of the surface of the grain material in a color format for analyzing the shape and quality of its particles.

As a result of data processing, the device sorts the grain and removes particles from the grain material that do not meet the requirements for geometric parameters and shape, which allows statistical processing and analysis of data based on the requirements. Device systems count the number of particles of grain material, and save them.
2. Research results

The installation (figure 1) for processing bulk raw materials of plant origin [1] consists of: frame 1, a receiving hopper 2, at the base of which a valve 3 is installed that regulates the productivity of the device, feeding grain flow to the grain chute 4. The valve 3 is driven by a crank-and-rod mechanism 5 connected to the motor 6. On the grain chute 4 and the valve 3 there are wedge-shaped channels 7 and 8 installed. Two optical sensors 9 and 10 are installed one after the other on one side of the grain chute 4, and a receiving hopper 11 is located behind the grain chute 4. The receiving hopper 11 is placed with its bottom side to the receiving hopper 12 for collecting clean grain material. Between the grain chute 4 and the receiving hopper 11 there is a mechanism for removing particles that do not meet the requirements. The substandard particle removal mechanism consists of an electric motor 13 driving a crank-and-rod mechanism 14, which converts rotational motion of piston 15 into the reciprocating. Piston 15 is located in the zone 16 for identifying substandard grain. After the crank-and-rod mechanism 14, a receiving hopper for substandard grain is designed in the installation where from the grain flows to the hole 17. Under the hole 17 there is a container 18 for substandard material and impurities.

Sensors 9 and 10 are equipped with cameras, which are high-speed CCD photosensitive digital devices. Two cameras are installed in such a way that they can determine the thickness of the passing particles and other geometric dimensions fixed on the grain chute 4. To identify the thickness of the particles, the camera 19 is located above at an angle to the chute 4. The camera 20 is located below perpendicular to the chute 4 for identifying shapes and colors of particles. To illuminate the working area, LEDs 21 are located in a line on the sides of the digital cameras.

To protect the sensors 9 and 10, glasses are installed in front of them, which are equipped with mechanisms for dust and other cleaning.

The control panel with devices, the power supply unit, control units are not shown in figure 1 and are located at the bottom of the installation frame.

The control unit of the installation, shown in figure 1, includes: a system for monitoring and adjusting the degree of illumination of the working area with LED lines 21, fed through the switches from the power supply; a system for determining the geometric and color parameters of particles, which includes digital cameras 19 and 20; substandard grain rejection system, receiving commands from a digital image processing system.

The main processor controls the listed systems.

The developed device operation procedure.

Bulk raw materials of plant origin are fed into the receiving hopper 2, where the valve 3 is closed. The device operator supplies power to the device with a button, closing the electrical contacts installed on the control panel. Then the operator sets the necessary brightness of the LEDs 21 located in line to illuminate the zone 16 to identify substandard grain. The valve 3 is opened and it sets the required performance of the device. Grain particles are fed into the grain chute 4, where they unfold and are located by the length along the flow in the wedge-shaped channels 7. Moving in the wedge-shaped channels 7 of the inclined grain chute 4, the reoriented grain enters the zone 16 for identifying substandard grain. Optical sensors 9 and 10 sort out passing grain material. In zone 16, the working zone is illuminated by LEDs 21. The LEDs are arranged in a line perpendicular to the grain path. The switch supplies the required amount of energy to the LEDs from the device’s power supply.

The main processor using software analyzes the digital image coming from the cameras in real time. By analyzing digital images, substandard grains that differ from the set values and requirements are detected and fixed. The system also detects impurities not related to grain material. The processor sends a signal to the rejection system for substandard grain and impurities. An electric motor 13 is started, which, through the crank mechanism 14, drives the piston 15, which pushes or discards the detected particles that do not meet the requirements. Particles are thrown into the feed hopper, where they roll into the hole 17 and then enter the tank 18. The grain that meets all the specified requirements enters the receiving hopper 12.
2.1. Diagram of a device for cleaning and sorting grain
The device for cleaning and sorting grain has hardware and software. The hardware of the device for cleaning and sorting grain consists of a receiving hopper 2, at the base of which there is a valve 3, a grain chute 4, where the grains are unfold by the length along the flow in the wedge-shaped channels 7. Grain moving in the wedge-shaped channels 7 of the pitched board 4, enters the zone 16 of identification of substandard grain. Optical sensors 9 and 10 perform the process of rejecting passing grain and are included in the digital vision system (DVS).

2.2. The device for cleaning and sorting grain
The digital vision system consists of a pair of digital high-speed cameras, LEDs mounted linearly to illuminate the working area, a grain chute with wedge-shaped channels and digitizing boards using analog video cameras. SCZ determines the geometric dimensions of each particle of the grain material (thickness, width, length and shape of the particles of the grain material), color and damage by individual digital images from the video stream [8]. The real-time digital vision system is capable of transmitting images of the workspace to the central processor for processing.

Modern high-speed digital cameras send digital information directly without prior digitization which speeds up the entire process of cleaning grain material. The computer processes the incoming digital image through the existing standard ports IEEE1394, i-Link, USB, FireWire from the cameras.

The main camera is mounted to fix all grain and particle characteristics except thickness. Such characteristics include: the shape of the grain and particles, the length and width, as well as the color of the studied grain material. The camera is mounted above the grain chute so that the surface of the chute is perpendicular to the main optical axis of the camera lens.

The next camera is mounted at an appropriate angle to the surface of the chute. The angle is set to accurately determine the thickness of the grain material without blocking the view of other particles.

Bulk material of plant origin enters chute with wedge-shaped channels from the feed hopper through a slit-like opening. The gap of the slit-like hole is set so that the grain material is fed to the chute in one layer to correctly determine the grain material. Otherwise, the digital image of the boundaries of the particles of the grain material of one layer will be superimposed on the image of the boundaries of the other layer thus leading to a wrong determination of the particle sizes of the grain material. The grain cleaned from impurities is fed to the tank through the receiving hopper.

Figure 1. Grain cleaning and sorting installation: 1 – Frame; 2 – receiving hopper; 3 – valve; 4 – grain chute; 5 – crank-and-rod structure; 6 – motor; 9, 10 – optical sensors; 11 – receiving hopper; 12 – receiving tank; 13 – electric motor; 14 – crank-and-rod mechanism; 15 – piston; 16 – substandard grain identification zone; 17 – hole for rejected grain; 18 – tank for substandard grain and impurities; 19, 20 – photo cameras; 21 – LEDs; 22 – protective classes.
2.3. Grain cleaning and sorting device software

The software is presented by the following modules: a module for counting particles of grain material; a module for calibrating a digital vision system; a module for capturing digital images of particles of grain material on a chute; primary processing of digital images; a module for determining thresholds for binarization; segmentation for determining the boundaries of particles of grain material; calculating grain sizes and components of the processed materials; determining substandard grain in the flow and fixing the color of grain and flow particles; controlling the selection of defective grains and removing impurities; controlling grain sorting; processing statistical data; for example, determining average values of the main particle sizes of grain material.

2.4. Digital images of particles of grain material

Digital images of grain material on an inclined chute are transmitted from digital cameras via USB or FireWire (IEEE1394) to a computer. The video frame-by-frame library - Microsoft Video for Windows SDK (AVICAP32.DLL) is used to obtain digital images of particles of grain material. The library allows to capture digital images from a video signal, to save captured digital images in __. Bmp format on a computer, as well as record a video signal in __. avi format without preview, but with sound.

2.5. Setting up digital cameras

The degree of reliability and accuracy of the digital data coming from the cameras depends on the setting of the digital cameras including the calibration process. The authenticity of the transmitted geometric dimensions of grain and particles depends on calibration. The digital camera calibration process consists of two steps. The first step is to configure the internal performance of digital cameras. The second step is to configure the external characteristics of digital cameras.

Setting the internal parameters of digital cameras is reduced to solving a number of problems: eliminating image distortion by the camera lens due to uneven enlargement of objects, finding the area of intersection of the plane of the chute with the optical axis of the camera lens, calculating the distance from the surface of the chute to the optical center of the lens, eliminating image distortion by camera lenses as much as possible, as well as solving the problem of finding the zoom factor of camera lens images of particles of grain material.

Setting the external characteristics of digital cameras is limited by the coordinate system of the studied area and determining the angle of rotation of the camera in this area, as well as establishing the position of the camera.

To apply mathematical techniques in projective geometry it is proposed to position the regular hexagon on the surface of the working area of the chute, which will allow to find the necessary camera parameters.

Let’s place the regular hexagon on the surface of the working area of the chute and denote its angles as R1, R2, R3, R4, R5, R6 (figure 2). The surface of the working area of the chute is denoted by the plane Π. The x and y coordinate axes are arranged in the plane so that the 0x axis is parallel to the hexagon side R1 R2. In the plane A of the lens, we place the image of the hexagon R1 ’, R2’, R3 ’, R4’, R5 ’, R6’. Let us denote the angles of the relative position of the lens plane A relative to the plane Π: φ is the pitch angle, ψ is the angle of roll, and α is the angle of the course.

The working plane created by the flow of grain material is defined by the x, y axes. We get the coordinate system x, y, z. We define the coordinate system k, j, c, where the k, j axes are located in the plane Π. The axis of the camera lens lies on the c axis of the given coordinate system k, j, c. We arbitrarily denote the optical center of the camera lenses by the letter S lying on the c axis.

The center of the coordinate system k, j, c and the lowered perpendicular to plane A from the optical center S coincide at the point denoted by the letter K ’. The point is simultaneously the origin of coordinates k, j, c and the point of intersection of the axis of the camera lenses with the plane k, j. The length from the point S of the optical center of the camera lenses to the plane k, j is denoted by the letter l.
In figure 2, plane A is represented between points S and plane \( \Pi \); this arrangement is not true. Since the plane A is not in front of the point S. The letter K marks the region of intersection of the plane \( \Pi \) with the \( c \) axis. The segment from the point K 'to the point K is denoted by the letter q. By the symbol n we denote the projection scale of the geometric dimensions of the particles of the grain material on the plane A and from the plane \( \Pi \).

![Figure 2. Relative position of plane A and plane \( \Pi \).](image)

2.6. Determination of the intersection of the optical axis of the camera lenses with the working surface of the image

To adjust the parameters of the camera and its calibration, it is necessary to determine the intersection of surface A with the main axis of the camera lenses. The camera has a function to change the focal position of the lenses of the camera lens, which will allow to use this mode to solve this problem. It is necessary to have a sheet of paper in the shape of a rectangle, pre-painted if necessary in a bright color, set on a dark tablet.

The tablet is mounted and fixed perpendicular to the optical axis of the digital camera. As shown in figure 3, the rectangular shapes of the sheet and tablet are drawn from the pictures taken by the camera.

We number the angles of the rectangle in figure 3, respectively, from 1 to 4 at the first focal position, and number the corners of the rectangle in figure 3 with numbers 1 'to 4' at another focal position. Then we get our necessary point K '.

Since the plane A and the optical axis of the camera lenses intersect the point K ', the coordinates of the point K' remain constant for other focal values.

Making several measurements and carrying out the corresponding calculations, we got the exact data of the point K', namely its coordinates \((k_K, j_K)\).

Once the coordinates of the intersection point K 'with the plane A and the optical line of the camera lenses are determined, it is necessary to calculate the segment from the plane A to the optical center or from the center of the projection. After that, it is possible to determine the scaling factor of the camera lens images of particles of grain material.
3. Conclusion
Modern digital technical means for processing grain material, the work of which is based on the use of technical vision, largely depends on the settings of digital cameras, including the calibration process, which affects the degree of reliability and accuracy of the received digital data coming from the cameras. We examined the process of calibrating digital cameras, including setting internal indicators and external characteristics of digital cameras. Through the use of a system for changing the focal position of a camera’s photo lens, the intersection of the optical axis of the camera’s lenses with the working surface of the device is determined.

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