The Silkworm Eggs Separator with the Novel Electronic Computing Unit

Mirzakhodjaev A., Mirzakhodjaev B.A., Bazarov D.K., Dadajanova D.X., Bazarov R.K.

Abstract: The article presents the results of research aimed to develop software and hardware for silkworm separating device by their colors. The device consist of four main blocks. The first one is designed for eggs feeding in portions, the second for the sequence of eggs alignment, the third is to bring these eggs to estimation zone, where the fourth analyzes and separates light eggs from dark ones.

Each unit is an element of a queuing system with measured value of the flow parameter. Each unit of the device is treated as a queuing system element with a specified flow parameter value. Based on their equality the conclusion is made about the required performance of the webcam for the analysis block. The scheme of the control device and the algorithm of silkworm's recognition are given.

The Study and analysis showed that the separation of silkworm eggs is better carried out by piece-oriented feeding it to recognition zone, developed on the basis of computer vision using a high-speed web-camera. It is also proposed to use Arduino UNO R3 as a hardware platform. The developed hardware and software for analysis and processing of data on determination of color of eggs of silkworm of the developed device on a stationary platform is described.

***Keywords* :Silkworm eggs , separator, single-board computer**

I. INTRODUCTION

All the industrial sericulture based on feeding silkworm hybrids. In the production of high-quality hybrid silkworm eggs it is very important to separate the silkworm by sex with high accuracy, so that the females of one breed will be crossed with the males of the other and vice versa.

The practical implementation of this seemingly simple operation in a production environment is very difficult, due to the lack of appropriate engineering and technology, and therefore until now it is not possible to provide a pure separation of silkworm eggs by sex. The factors complicating the separation process are: oil content, small size and weight, low survivabilityof the silkworm eggs. The article proposes a method, a mathematical model of the device and its implementation for the separation of silkworm eggs by the color at the egg stage, ensuring minimal mechanical effects on the objects under separation.

Today, a large number of silkworm separating ways are known, but no one meets the needs ofsericulturists. The purpose of separation in agriculture is to remove impurities (weed seeds) that differ from the original in shape, color or weight. The parameters for assessing the quality of separation are: productivity (kg / h) and efficiency (%).

The most of separators comprises the devices for suppling, transporting to the analyzer zone, recognizing, separating and a collecting of some fine- (rape, poppy, alfalfa) or coarse-grained objects (barley, rye, oats, corn, sunflower, wheat).

In addition, separators are distinguished by

(I) the type of transporting device of objects to the analyzer of the luminous flux to the electricdrive, air vent, single and multi-threaded.

(II) the type of actuating mechanism for pneumatic separators and electro-mechanical.

(III) according to the type of analyzer of the light flux sensory and with CCD-camera.

(IV) according to the method of separation of the components of the separated material: by color, shape, size, density, aerodynamic properties of the object of separation.

The device being developed is a single-flow electrically driven coarse-grained photoseparator with a CCD camera that performs sorting of homogeneous objects by color using an electro-mechanical actuation device.

The method of separation silkworm at the egg stage is the most effective separation way. Two silkworm greed's tagged by color had issued for this purpose [1-3], the dark greed's are female and the light ones are male (Fig. 1)

There is a machine for separation silkworm eggs by their color, based on a photomultiplier tube, the vacuum device with some electrodes, cathode, anode and the actuator inside it [4]. The main disadvantages of that device are: high error of eggs separation, a limited lifetime of the photomultiplier tube (about 500 hours), the need for a high-voltage power source (from 500 to 1500V) to enhance the photocurrent in the photomultiplier, which leads to high power consumption of the device.

Manuscript published on January 30, 2020.

* Correspondence Author

AnvarMirzakhodjaev,Phd of engineering. Head of the laboratory of mechanization of sericulture, Research Institute of Sericulture, Tashkent, Uzbekistan, uzniish@yandex.ru

BakhtiarAnvarovich. Mirzakhodjaev*, Phd of engineering sciences, Research Institute of Sericulture, Tashkent, Uzbekistan, mir_bah_66@mail.ru

DmitriyKamilevichBazarov, senior researcher,Research Institute of Sericulture,Tashkent,Uzbekistan, standina@mail.ru,

DildoraXamidjanovnaDadajanova, junior researcher Research Institute of Sericulture, Uzbekistan, Tashkent, ddilya_92@mail.ru.

RustamKamilevichBazarov, doctoral candidate, Tashkent university of infrormation technologies named after Muhammad al-Khwarizmi, Tashkent,Uzbekistan,rustam.bazarov@gmail.com

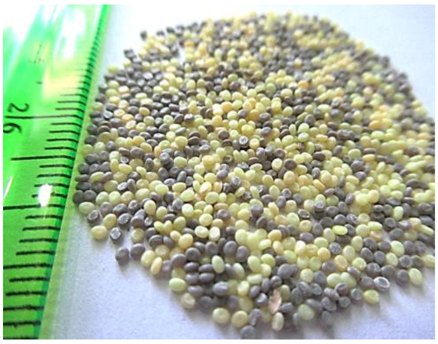

Fig.1. Silkworm eggs tagged by color.

The objective of this publication is to substitute the photomultiplier tube with the electronic-computing unit (ECU) based on single-board computer and estimate the benefit of that substitution. We will also evaluate the time interval between signals to the actuator of the ECU based on the mathematical model proposed below for the eggs separator.

II. MATERIAL AND METHODS

The machine under development contains four main worker units: a silkworm egg dispenser, a forming unit, a transportation mechanism, and the ECU. The main purpose of the first three units is to deliver a sequence of dark and light eggs, that are equidistant from each other, to the "analysis zone", the area of operation of the third block, which actually sorts eggs by their color. In fig. 2 (a) is represented a diagram of the automaton and in fig. 3 (b) the section of the machine

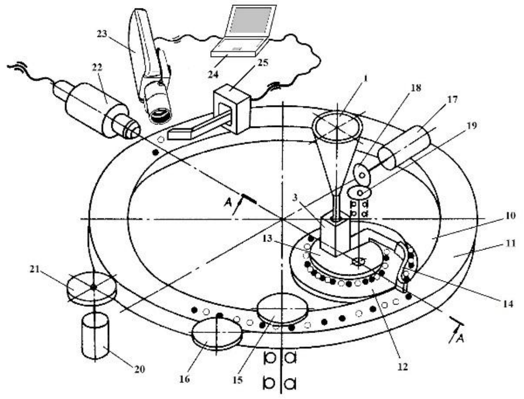

Fig. 2. The scheme of the automation for silkworm eggs separation by color.

The clue requirement of the separator as a queuing system is the equation of parameters of incoming and outgoing flows of "requests". In our case, the flow parameter is the number of eggs served by that machine per second. Since the eggs are transmitted sequentially from one unit of the machine to another, the requirement of equality of the flow parameters must be fulfilled for each device separately: the egg dispenser (ED), the forming unit (FU), the transportation unit (FU) and ECU:

$$Q_{ED} = Q_{FU} = Q_{TU} = Q_{ECU} .$$

Let us consider each block of the automation separately.

2.1. THE SILKWORMEGG DISPENSER

The silkworm egg dispenser is designed to eggs feeding in portions. It supplied with a conical tank (1) for eggs loading and feeding device installed at the neck of the latter. The feeding device is made in the form of body (3), installed in a cylindrical chamber (2) over bearing (4) of the grooved coil (5) with sockets for eggs. The last has two lateral shoulders (6) and (7), the diameter of which is equal to the diameter of the chamber, and it is larger then the one of the grooved coil. All of them, in the aggregate, form an circular space, communicating with tank 1 through the opening (8) of the body (3). Width of this body is equal to twice the diameter of the egg, to ensure the of the egg's passage without injury. One of the shoulders (6), provided with a rubber ring (9), is in friction engagement with the forming disk of the forming unit. Moreover, the teeth of the grooved coil (5) have a wave-like shape. The tooth size and teeth spacing provide 4-5 eggs portions transfer, that protecting the eggs from injury. There is a window for the eggs exit, in the bottom part of the body (3).

If each of Z coil sockets contains m eggs, then the number of eggs emitted by the ED after a full turn of its rotation ($2 \cdot \pi$ radians) is $Z \cdot m$. Consequently, the portion of eggs arriving every second from the ED to the FU disk is the number of eggs in the sector equal to the angular velocity ω_{ED} of the ED coil. Taking into account the coil slippage with the coefficient η the formula for the ED flow parameter will be:

$$Q_n = \frac{Z \cdot m \cdot \omega_{ED} \cdot \eta}{2 \cdot \pi} = 8{,}71 \approx 9\, egg/s$$

where

$$Z = 12,\ m = 4,\ \omega_{ED} = 1{,}2 rad/s, \eta = 095$$

The angular velocity of rotation of the coil is found by the formula $\omega = 2 \cdot \pi / T$, where T , the period of its rotation, is determined experimentally. Other parameters for the rotating disks of the machine are obtained similarly. These data are summarized in (Table 1).

Table I. The semidiameters, periods, angular and linear speeds of the machine disks.

Theunit	Radius R, m	Period T, s	Angularspeed $\omega = 2 \cdot \pi / T$, rad/s	Linearspeed $V = \omega \cdot R$, m/s
ED	0,013	5,24	1,2	-
FU	0.09	10,4	0.6	0.05
TU	0.2	16.17	0.39	0.078

2.2 THE FORMATION AND TRANSPORTAION UNITS

The formation and transfer mechanism is designed for to place the eggs in a chain, one after the other, with given interval between them. It is composed of the disks, one of which has a working surface made in the form of a ring 1, and other, a forming disk (12), installed inside one so, that working surfaces of the both are on the same level. Another parts of the mechanism are the fixed guide rail (13) in the form of an Archimedean spiral and the baffle (14), a curved bar, one end of which is connected to the rail, and the other is bent by the

0.3 mm towards the circular part (11) of the transporting disk (10) via the convergence point of the disks (10) and (12). The fixed rail (13) starts from the position of the forming disk (12), where it's line speed is equal to required one of the grooved coil 5. In that zone the fixed rail (13) and the forming disk (12) made up a cavity for locating the feeding device. It is composed of the disks, one of which has a working surface made in the form of a ring (1), and other, a forming disk (12), installed inside one so, that working surfaces of the both are on the same level.

The eggs are transferred to the analysis zone and fixed there by a frictional engaged rubber rollers (15) and (16), located on ring part surface (11) of the transporting disk.

The drive of the forming disk (12) is carried out by the electric motor (17) through a pair of interchangeable gears (18) and (19), designed to adjust the speed of rotation of the forming disk (12), and the drive of the transporting disk (10) is driven by an electric motor (20) and a friction pair (21).

According to the equation of the Archimedean spiral:

$$\rho(\phi) = k \cdot \phi \quad (2)$$

the module of its radius-vector is proportional to the angle of rotation, where the proportionality coefficient is chosen equal to $k = 0{,}0075 m/rad$. The length of the formation zone, the section of the spiral, along which the eggs line up, on the one hand, is the product of the nominal diameter and the number of eggs in this zone, and on the other hand, the excess path, traveled by the egg per second due to the velocity difference at the beginning and end of the formation:

$$d \cdot Q_{ED} = b \cdot (V_F - V_0) \quad (3)$$

where $b = 0.8$ is a correction factor that takes into account the slowing down of the translational movement of the egg due to its rotation, as a consequence of friction, and $d = 1{,}1 \cdot 10^{-3} m$ is a nominal diameter of the egg (a half-sum of its length and width).

For a given radius of the spiral at the beginning $\rho_0 = 0.038$ m and at the end $\rho_F = 0.083$ m of the formation, it is easy to find the corresponding angles $\phi_0 = 5\, rad$ and $\phi_f = 11\, rad$ by formula 2.

The dependence of the linear velocity of the eggs at each point of the formation zone on the angle of rotation of the FU disk (in the absence of friction) is expressed by the known relation: $V(\varphi) = k \cdot \omega_F \cdot \sqrt{(1+\phi^2)}$,

where

$$\omega_F = 0.6 rad/s$$

see Table 1.

Substituting the values of the angles here, we find the speeds and of the egg at the beginning $V_0 = 0.023\, m/s$ and at the end $V_F = 0.05\, m/s$ of the formation stage. According to them and to the formula (3), we determine the parameter $Q_{ED} = 15\, egg/s$ of the flow, that theoretically can be served by the FU. But since the actual value of the ED parameter is almost one and a half times less than former one $Q_{ED} = 9\, egg/s$ (formula 1), the gaps between eggs up to 1.5 nominal diameter are already formed at the formation stage.

The separation with a minimum error is ensured when the gap between the eggs on the transporting unit (TU) of at least two of its nominal diameters. If the linear speed of the TU disk will be at least twice the linear speed of the FU disk:

$$V_T \geq 2 \cdot V_\Phi$$

then this will ensure the required distance between eggs on the TU.

Indeed, the linear velocity ratio:

$$\frac{V_{TU}}{V_{FU} \cdot b} = 0.078 / 0.04 = 1{,}95 \approx 2$$

of the egg on TU and FU disks provides that distance.

2.3. THE ELECTRONIC-COMPUTING UNIT

At the positions of the analysis, eggs are classified by color and divided into two, groups, male and female, by the ECU 24 whose block diagram is shown in Figure 3. This unit is connected to both webcam and actuator 25.

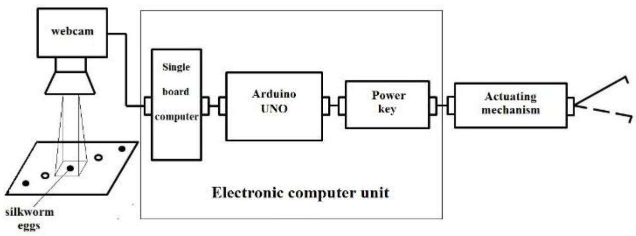

Fig. 3. Engine control unit of the automation for dividing silkworm eggs by color.

The ECU of the machine is represented by: the webcam G-LENS Defender 2597, Arduino UNO microcontroller board based on Microchip ATmega328P, the single board computer Raspberry Pi 3B+ and the power key: Troyka module AMP B098.

Supposing the distance between the centers of any two eggs is equal to $3 \cdot d$, and the analysis zone is limited to the nominaldiameter, the eggs will appear every

$$t = \frac{3 \cdot d}{V_T} = \frac{0.0033}{0.78} = 0.042\, s$$

in front of the ECU webcam, which is equivalent to $Q_{TU} = 1/t = 23\, egg/s$ for flow parateter of the TU. We can conclude, that the webcam, provided shooting up to 30 frames per second, has enough time to transmit at least one photograph of the screen to the ECU (24) for its subsequent analysis, issuing a control signal (1ms) and triggering the actuator (3 ms).

2.4.THE PRINCIPLE OF OPERATION

The machine works as follows. Silkworm eggs are poured into a conical tank (1) of the dispenser, from where they are enters the chamber (2) with side collars (6) and (7), through the opening (8) of the body (3). Then, the transporting (10) and forming (12) disks are driven. The grooved coil 5 is rotating, due to the friction between the forming disk (12) and the rubber ring (9). That rotating fills the volume between teeth, and silkworm eggs enters on the surface of the disk (12). The FU transfers the eggs to the fixed guide rail (13). Then, placed in a chain on the surface and, moving one by one, these eggs get into the zone of action of the baffle (14) and at its edge, changing the direction, smoothly passes to the surface of the circular part (11) of the transporting disk (10). Due to the difference in linear speeds of the disks (10) and (11) (at this point, the speed of the transporting disk (10) is about 2 times greater one of the forming disk (12)), the silkworm eggs are separated from each other and transported further by disk (10).

signal is assumed to be 23ms. The results in both cases of separation are given in Table II.

Table II. Setting up the automation for selecting dark(light)silkworm eggs for the breeds of silkworm eggs.

Breed (separated by color)	Eggs	Light		Error, %	Dark		Error, %	Losses		Relation			
		♂	♀		♀	♂		eggs	%				
B1(light)	1045	428	33	7,8	527	37	7,3	18	1,7	474	570	45,6	54,4
B1(dark)	1067	490	17	3,5	519	19	3,8	20	1,9	522	544	48,9	51,1
B2(light)	1040	438	29	6,7	517	36	7,1	18	1,8	486	554	46,7	53,3
B2(dark)	1038	456	23	5,2	509	25	5,0	22	2,2	494	543	47,5	52,5
S8(light)	1075	492	35	7,0	491	38	7,8	19	1,8	538	537	50,0	50,0
S8(dark)	1078	478	24	5,2	520	26	5,1	23	2,2	516	556	47,8	51,7
S9(dark)	1050	466	29	6,4	499	33	6,7	21	2,0	512	538	48,6	51,4
S9(light)	1031	451	20	4,5	515	21	4,2	23	2,2	484	546	46,9	53,1

Rubber rollers (15) and (16) align the eggs in line to the analysis zone of the ECU, where they are classified according to color to male and female individuals.

The video stream from webcam (23) is processed by a special program [5], installed on the single-board computer of the ECU. If an egg is light, the program generates control signal to the actuator 25, the electromagnetic relay with a lever. It pushes that egg back into the corresponding box. For a dark-colored egg, appeared at the analysis position, the signal from the ECU is not received by the actuator (25), and the egg is transported further to the other box.

The special program [5], the block-diagram of which is presented in (Fig. 4), is written using the computer vision library OpenCV and has installed on a single-board computer with the Raspbian operating system.

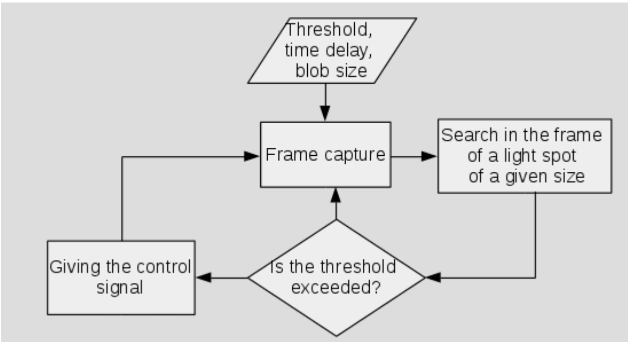

Fig.4 . A block diagram of the object recognition algorithm by color.

The relay trigger threshold, a digital representation of the spot brightness, its size and the delay interval between signals to the actuator, are depending on external factors: illumination and temperature in the room where the machine is located. These parameters are determined, therefore, during a computational experiment and in our case they are: threshold=198, spotsize = 16 px, time delay = 23 ms.

III. RESULT AND DISCUSSION

In 2019 we nourished silkworm eggs of Belokokonnaya-1, Belokokonnaya-2, Saniish-8 and Saniish-9 (B1,B2,S8,S9) breeds for our experiment. Program control of the automation was carried out per breeds and color of the eggs. Based on the above calculations, the delay time in issuing the control

When setting up the automation for the selection oflight eggs, the separation errorwas 6.7-7.8% for “B-1” and “B-2” and 6,4-7,8% for “S-8” and “S-9”.

With the dark silkworm eggs configuration, the error in the range from 3,5 to 5,2% for both groups of “Belokokonnaya” and from 4,2to 5,2% for “Saniish” breeds.

A sufficiently high error when selecting by light eggs is caused by the low contrast between the color of light silkworm eggs and the color of the transporting disk. So at high rotation speed, an egg merges with the background of the disk surface and webcam cannot always recognize it.

Further we plan to increase the separation accuracy by more precise illumination of eggs and choosing an optimal rotation speed of the transporting disk.

The recoverable losses of silkworm eggs were in the range of 1.7-2.2%, which corresponds to required parameters.

IV. CONCLUSION

The developed machine will allow high performance and accuracy separating the silkworm eggs, labeled by color, at the silkworm stations and plants for further production of the industrial hybrid, purebred, and male-only caterpillars, which are giving cocoons greater silkiness than female ones. Thus, the use of the device of such design will ensure reliability in operation, easiness of maintenance, high performance and accuracy, as well as eliminate silkworm egg's injuries and even it's minimal losses. It will allow to introduce new hybrids of the silkworm in production, and produce non-clogged, 100% hybrid silkworm eggs, which will give increased yields of cocoons with high technological properties of the raw silk and silkworm yarn.

The contents of the journal are peer-reviewed and archival. The journal publishes scholarly articles of archival value as well as tutorial expositions and critical reviews of classical subjects and topics of current interest.

Authors should consider the following points:

1) Technical papers submitted for publication must advance the state of knowledge and must cite relevant prior work.
2) The length of a submitted paper should be commensurate with the importance, or appropriate to the complexity, of the work. For example, an

obvious extension of previously published work might not be appropriate for publication or might be adequately treated in just a few pages.

3) Authors must convince both peer reviewers and the editors of the scientific and technical merit of a paper; the standards of proof are higher when extraordinary or unexpected results are reported.
4) Because replication is required for scientific progress, papers submitted for publication must provide sufficient information to allow readers to perform similar experiments or calculations and use the reported results. Although not everything need be disclosed, a paper must contain new, useable, and fully described information. For example, a specimen's chemical composition need not be reported if the main purpose of a paper is to introduce a new measurement technique. Authors should expect to be challenged by reviewers if the results are not supported by adequate data and critical details.

ACKNOWLEDGMENT

This work was supported by Ministry of Innovative Development of the Republic of Uzbekistan under research grant “F-A-2018-015”

REFERENCES

1. Strunnikov V.A. Ispolzovaniegeneticheskixmetodov v selektsiitutovogoshelkopryada. // Sat. science. wr. SANIISH anniversary edition - Tashkent, Fan, 1971. – P.40-48.
2. Larkina E.A, Abdukayumova N. Perspektivyispolzovaniyamechenyxpopolunastadiigrenyporodmirovoy kollektsiitutovogoshelkopryada. //Jr. Young scientist. - Moskva, 2018, №50, ch1. – P.52
3. Larkina E.A. and ot. Katalog. Genetic Fund of the world collection of silkworm of Uzbekistan. – Tashkent. 2012., – P. 56.
4. Mirzahodjaev A, Mirzahodjaev B.A, Bazarov R.K, Dadajanova D.X. Ustroystvorazdeleniyagrenytutovogoshelkopryadapotsvetu.//Jr. Agro Ilm. – Tashkent 2019., №1 – P.32.
5. Certificate of official registration of the computer program № DGU 05601. Device software division of tribal silkworm eggs silkworm on the gender. Mirzaxodjaev B.A, Bazarov R.K, Bazarov D.K, Dadajanova D.X. 2018.

AUTHORS PROFILE

AnvarMirzakhodjaev, Phd of engineering. Head of the laboratory of mechanization of sericulture. He graduated from Tashkent Institute of textile and light industry.
Area of interest - development of new methods, technologies and technical means for the processes of the sericulture industry. Author of 31 patents

BakhtiarAnvarovich. Mirzakhodjaev Phd of engineering.fromResearchInstitute of Sericulture, senior researcher of the laboratory of mechanization of sericulture. He graduated from Tashkent Institute of textile and light industry. Area of interest - development of new methods, technologies and technical means for the processes of the sericulture industry. Author of 5 patents.

DmitriyKamilevichBazarov, master of medicineat the Tashkent Medical pediatric institute in 1996, senior researcherfrom Research Institute of Sericulture. Scientific interests are: distributed computing systems for biomedical research, medical information systems, Uzbekistan, Tashkent100055, Ipackchi street, 1.

DildoraXamidjanovnaDadajanova, junior researcher of the laboratory of mechanization of sericulture. She is an undergraduate ofTashkent Institute of textile and light industry. Area of interest - development of new methods, technologies and technical means for the processes of the sericulture industry.

RustamKamilevichBazarov, master of telecommunications in June 2001 at the at the Tashkent university of information technologies named after Muhammad al-Khwarizmi., doctoral candidate the same institute. Scientific fields: grid-, gpu-, cloud-, multiagent-, edge-computing,systems, chemical and medical informatics.