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OPTIMIZATION OF PARAMETERS OF ENERGY-EFFICIENT AUTOMATED CONTROL OF THE PROCESS OF SORTING APPLES WITH THE RECOGNIZATION OF THEIR VARIETIES

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ОПТИМІЗАЦІЯ ПАРАМЕТРІВ ЕНЕРГОЕФЕКТИВНОГО АВТОМАТИЗОВАНОГО КЕРУВАННЯ ПРОЦЕСОМ СОРТУВАННЯ ЯБЛУК ІЗ РОЗПІЗНАВАННЯМ ЇХ РІЗНОВИДІВ

Objective*. The purpose of the article is to optimize the parameters of energy-efficient automated control of the apple sorting process with the recognition of their varieties.*

Methods*. In the work, to evaluate groups of closely spaced objects and extract apples from a set of options to be selected from the general flow, multi-criteria selection methods were used, namely: lexicographic, ideal point, selection by the main criterion, convolution. specific criteria.*

Results*. It is noted that today it is difficult to imagine the functioning of any technological facility, including food sorting processes, without an automated control system. Enterprises must not only ensure the safety and sustainability of technical processes, but also constantly improve their economic efficiency. It is believed that the automation of sorting processes is one of the most relevant areas in the food industry. However, so far the sorting process has not been considered holistically, taking into account the methodological, theoretical and technological components. Therefore, one of the main ways to improve the efficiency of the technological process is, of course, the improvement of technology and modes of technological processes at the enterprise. Attention is focused on the fact that significant effects can be achieved by improving automated process control systems by including in their structure the system of the intellectual component of the mathematical apparatus operating on the basis of fuzzy logic algorithms, neural networks, etc. A comprehensive analysis of the methods of multi-criteria choice was carried out, namely: lexicographic, ideal point, selection of the main criterion, convolution of particular criteria. It is believed that automatic sorting methods are based on the formation of systems for selecting suitable parameters for solving object recognition problems. When qualitatively-quantitatively assessing the criterion of interfixation and selection of apples on the sorting device, the following characteristics are taken into account: size (d), weight (m), color (g). In this case, the centers of image fragments are located at points that correspond to the predicted coordinates of a given object, that is, they are identified using discriminant functions. Based on a comprehensive analysis, an algorithm is proposed with the inclusion of an intellectual component of a mathematical apparatus in the structure of the system, working on the basis of fuzzy logic algorithms. The proposed method for automatic sorting of apples is a promising direction for improving technical and economic indicators in food production.*

Key words*: sorting, automation, parameter optimization, sorting attachments, technological processes, apple, methods of rich-criteria selection, algorithm, grub industry.*

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Formulation of the problem. Today it is quite difficult to imagine the functioning of any technological facility without an automated control system, including the processes of sorting food products. Enterprises are forced not only to ensure the safety and sustainability of technological processes, but also to constantly improve their economic efficiency.

Of course, one of the main ways to improve the efficiency of technological processes is to improve the technology and modes of technological processes at the enterprise [1]. A significant effect can be obtained by improving automated process control systems with the inclusion in the structure of the system of the intellectual component of the mathematical apparatus operating on the basis of fuzzy logic algorithms, neural networks, etc. To separate the control algorithm for the apple sorting process, it is necessary to analyze the technological process, determine the place of the mathematical apparatus in the structure of the process control system.

Analysis of recent research and publications. Making an assessment between groups of closely spaced objects that must meet quality indicators is quite difficult. Therefore, it is advisable to use the methods of multi-criteria selection to extract apples from a variety of options to be selected from the general flow. The choice of the optimal variant requires consideration of appropriate approaches to solving the problem of sorting apples, including lexicographic, ideal points, the method of analyzing hierarchies, highlighting the main criterion, convolution of partial criteria, etc.

According to the lexicographic approach, in multicriteria optimization problems, both in a clear [2] and fuzzy [3] setting, first, particular criteria are ordered according to their degree of importance, and then each individual criterion is sequentially optimized from the most important to the least significant. The disadvantage of this group of methods is the ability to take into account only the fact of the advantage of one criterion over another, however, the degree of prevalence in this case is not taken into account, which can lead to an unjustified narrowing of the set of alternatives.

The application of the method of selecting the main criterion [4, 8, 9] is expedient if one of the particular criteria significantly exceeds the others in importance. In this case, the main criterion is considered the only one. The use of this approach when forming the management of the process of sorting apples is not advisable due to the lack of sufficiently significant advantages of private criteria, as well as the need to use special methods to justify the limiting values of private criteria in the process of converting them into restrictions.

Objective of the article — optimization of parameters of energy-efficient automated control of the process of sorting apples with recognition of their varieties.

Presentation of the main study material. Automatic sorting methods are based on the formation of a system for selecting appropriate parameters for solving object recognition problems. When forming a qualitatively quantitative assessment of the criterion for interfixation and selection of apples on a sorting device, the following features are taken into account: size (d), weight (m), color (g), (fig. 1).

Specific areas of the image containing apples with specified characteristics are scanned. In this case, the centers of the image fragments are located at the points corresponding to the

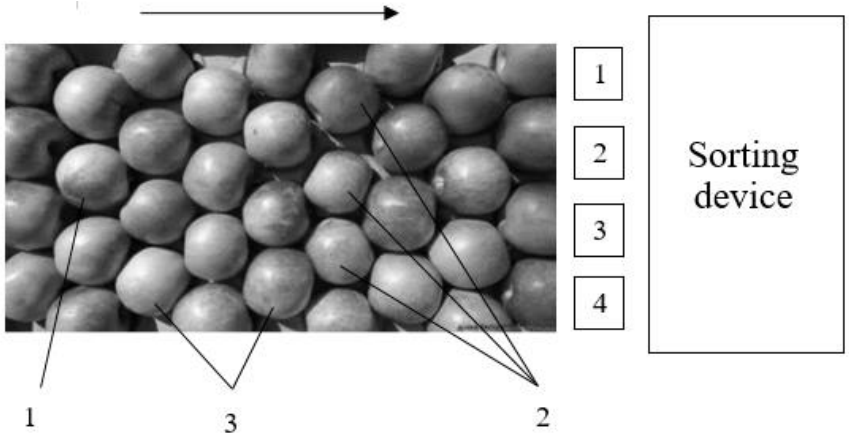

Figure 1 — Features of sorting apples 1 — apple to be selected; 2, 3 — location options

predicted coordinates of the given objects. Recognition of apples is carried out using discriminant functions.

$$x = (x_1, x_2, ..., x_n)^T, \quad (1)$$

where n — is the measuring vector of apple features.

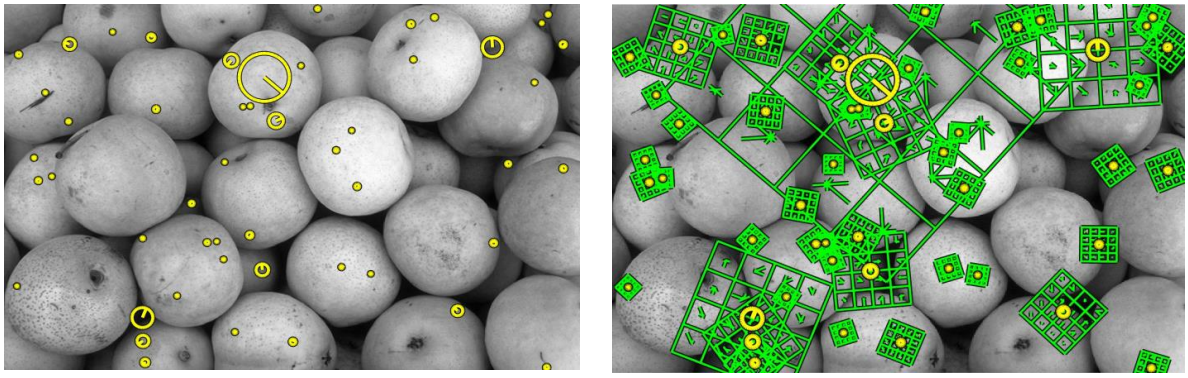

Figure 2 — The result of scanning some areas of the image flow of apples

Having W image classes w_1, w_2, w_w the recognition problem can be formulated as follows: you need to find W from functions $d_1(x)$, $d_1(x)$, ..., $d_w(x)$ that have properties such as i image x belonging to the class w_i, then

$$d_i(x) \succ d_j(x), j = 1,2,...,W, j \neq i. \quad (2)$$

An unknown image x is assigned to the i-th class if, during the substitution of x in all discriminants of the function, the value will have the greatest value $d_i(x)$ [5]. The distribution surface between classes w_i and w_j is the set of values x for which $d_i(x) = d_j(x)$ or the set of vectors x for which $d_i(x) - d_j(x) = 0$. The distribution surface between two classes can be described by a single function

$$d_{ij}(x) = d_i(x) - d_j(x) = 0, \quad (3)$$

where $d_{ij}(x) > 0$ — for class images w_i; $d_{ij}(x) < 0$ — for class images.

Finding the corresponding functions requires estimating the parameters of images that are representative of the given class. Feature vectors can be constructed based on quantitative descriptors for regions or boundaries. If the boundary is described using Fourier-descriptors, then the value of the i-th descriptor becomes the value x_i, that is, the i-th component of the feature vector. Let each class be defined by its averaging vector m_j, that is, the average value from the set of the given class is used as a representative (prototype) of the given class of vectors

$$m_j = \frac{1}{N_j} \sum_{x \in wj} x, \quad j = 1,2,...,W, \quad (4)$$

де Nj — number of class images w_i; W — number of image classes.

It is advisable to use the ability to reproduce an unknown image with a vector x to a certain class by choosing the class that has the prototype closest to the vector x. In this case, when using the euclidean distance as the degree of image density, the problem will be reduced to calculating the speed.

$$D_j(x) = \left\| x - m_j \right\| j = 1,2,...,W. \quad (5)$$

After that, the studied image will belong to the class w_i and will have the smallest distance $D_j(x)$. Therefore, the highest match will be determined based on the minimum distance to the prototype. If instead of one vector there are many feature vectors represented as rows of the matrix X, then you should get a matrix D, an element D (I, J), which will be equal to the euclidean distance from the i-th vector with X to the j-th prototype with M [5, 7]. In this case, in order to determine the

class of the *i*-th image from X, it is enough to find the column number in row i of the matrix X, which has a minimum value. It follows from this that the choice of the shortest distance will be equivalent to the described function

$$d_j(x) = x^T m_j - \frac{1}{2} m_J^T m_j, J = 1,2,...,W \quad (6)$$

assignment of x to the class w_i occurs at the highest value $d_i(x)$. The separating surface between classes w_i and w_j in the case of a classifier with a minimum distance is given by the equation

$$d_{ij}(x) = d_i(x) - d_j(x) = x^T (m_i - m_j - \frac{1}{2}\left(m_i - m_j\right)^T (m_i - m_j) = 0 \quad (7)$$

The surface given by this equation is perpendicular to the connecting segment m_i and m_j passes through its midpoint. The above algorithm operates with the size, weight, color of apples during the sorting process on the sorting device.

Therefore, a significant effect can be achieved by improving automated process control systems by including in their structure the system of the intellectual component of the mathematical apparatus operating on the basis of fuzzy logic algorithms, neural networks. It is proposed to scan certain areas of the image containing the desired apples according to the specified characteristics. When qualitatively-quantitatively assessing the criterion of interfixation and selection of apples on the sorting device, the following characteristics are taken into account: size(*d*), weight(*m*), color(*g*). In this case, the centers of image fragments are located at a point corresponding to the predicted coordinates of a given object, which is identifiable using discriminant functions. An algorithm is proposed with the inclusion in the structure of the system of an intellectual component of a mathematical apparatus operating on the basis of fuzzy logic algorithms.

Conclusions. Automation of sorting processes is one of the most relevant areas in the food industry. However, so far the sorting process has not been considered holistically, taking into account the methodological, theoretical and technological components. Therefore, one of the main ways to improve the efficiency of the technological process is, of course, the improvement of technology and modes of technological processes at the enterprise.

It is believed that automatic sorting methods are based on the formation of systems for selecting suitable parameters for solving object recognition problems. When qualitatively-quantitatively assessing the criterion of interfixation and selection of apples on the sorting device, the following characteristics are taken into account: size(*d*), weight(*m*), color(*g*). It is proposed to scan certain areas of the image containing the desired apples, according to the specified characteristics. In this case, the centers of image fragments are located at a point corresponding to the predicted coordinates of a given object, that is, they are identified using discriminant functions. On the basis of a complex analysis, an algorithm is proposed with the inclusion of an intellectual component of a mathematical apparatus in the structure of the system, working on the basis of fuzzy logic algorithms. The proposed method of automatic sorting of apples is a promising direction for improving the technical and economic indicators of food production.

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***Мета**. Метою статті є оптимізація параметрів енергоефективного автоматизованого керування процесом сортування яблук із розпізнаванням їх різновидів.*

***Методи**. У роботі для здійснення оцінки між групами розташованих щільно об'єктів та вилучення яблук, з множини варіантів, які підлягають відбору із загального потоку, було застосовано методи багатокритеріального вибору, а саме: лексикографічний, ідеальної точки, виділення головного критерію, згортки частинних критеріїв.*

***Результати**. Зазначено, що сьогодні важко уявити функціонування будь-якого технологічного об'єкта, в тому числі процесів сортування продуктів харчових, без автоматизованої системи управління. Підприємства мають не тільки забезпечувати безпеку та стійкість технічних процесів, а й постійно підвищувати їх економічну ефективність. Вважається, що автоматизація процесів сортування є одним з найбільш актуальних напрямків у харчовій*

промисловості. Проте досі процес сортування не було розглянуто цілісно, враховуючи методологічну, теоретичну та технологічну складову. Тому одним із основних шляхів підвищення ефективності технологічного процесу є, безумовно, удосконалення технології та режимів технологічних процесів на підприємстві. Сконцентровано увагу на тому, що значних ефектів можна досягти удосконаленням автоматизованих систем управління технологічними процесами шляхом включення в їх структуру системи інтелектуальної складової математичного апарату, який працює на підставі алгоритмів нечіткої логіки, нейронних мереж тощо. Здійснено комплексний аналіз методів багатокритеріального вибору, а саме: лексикографічний, ідеальної точки, виділення головного критерію, згортки частинних критеріїв. Вважається, що методи автоматичного сортування засновані на формуванні систем вибору відповідних параметрів для вирішення задач розпізнавання об'єктів. При якісно-кількісній оцінці критерію інтерфіксації та відбору яблук на сортувальному пристрої враховуються такі характеристики: розмір (d), маса (m), колір (g). Пропонується здійснювати сканування певних ділянок зображення, що містять шукані яблука, за вказаними характеристиками. При цьому, центри фрагментів зображення знаходяться в точці, що відповідає прогнозованим координатам даного об'єкта, тобто ідентифікуються за допомогою дискримінантних функцій. На основі комплексного аналізу запропоновано алгоритм із включенням в структуру системи інтелектуальної складової математичного апарату, який працює на підставі алгоритмів нечіткої логіки. Запропонований метод автоматичного сортування яблук є перспективним напрямком покращення техніко-економічних показників виробництва харчових продуктів.

***Ключові слова**: сортування, автоматизація, оптимізація параметрів, пристрій сортування, технологічні процеси, яблука, методи багатокритеріального вибору, алгоритм, харчова промисловість.*