Intelligent information systems

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INTELLIGENT APPROACHES TO ORGANIZING REMOTE QUALITY CONTROL OF STORAGE OF GRAIN PRODUCTS

Abstract. Cereals are an essential part of the diet of Homo sapiens. Since late Neolithic times, with the transition to sedentary farming, working with grain (growing, storing, processing, cooking food) has become a traditional type of professional human activity. As part of the accumulated historical experience, numerous technological processes have been developed and optimized for this type of activity. The relevant technologies evolved in close correlation with the changing conditions of life, literally under the pressure of Darwinian natural selection, because they were directly related to the survival of the Homo sapiens. Further development of grain-processing technologies remains invariably urgent today, as evidenced by the report [1] presented by the UN on the state of food security and nutrition in the world - with horrifying figures depicting the need and misery of the wide masses of the population of the planet. An important component of grain processing is the technology associated with the storage of grain products. Part of the stored grain products is used as seed stock for a new cycle of grain sales, the other - a significant part - for processing into food products. At the same time, new developed (optimized, improved) grain storage technologies must be safe, low-cost, maximally compatible with previously developed (available) equipment, and scalable to large volumes of stored material. Of course, the technology must ensure proper efficiency, an indicator of which should be a reduction in the percentage of grain product losses. In this regard, management methods used in the technological processes of grain products storage are substantially important, as well as methods of control over the current state of grain products for the correct organization of the technological processes. In particular, methods using elements of artificial intelligence are of high interest. Among them, neural networks are promising, especially those capable of learning "without a teacher" - Kohonen Maps (KK). Modified KK algorithm [2] implements reduced learning time[3], which is relevant in the implementation of adaptive procedures for processing the results of measurements of controlled parameters. The purpose of this paper is to consider the principles of using modified Kohonen maps to classify situations with applicability to remote quality control of grain products storage.

Keywords: Grain; Kohonen Maps; Conditions Identification System; Energy Saving.

Introduction

Briefly consider the elements of the subject area - methodology, equipment and storage conditions of grain products - in relation to the formulation of a general model representation for the organization of quality control systems of grain products storage.

At the moment, the main type of granaries are tower-type structures. They are built with the same standardized shape and unified design. The convenience of this approach is that the project - a typical and done once. Also the technology of erection is typical. No new technical technological solutions are required every time. The equipment that each tower is equipped with is also typical, i.e. it is produced in series and therefore has an increased repairability, interchangeability and completeness of spare parts. In the end, all this makes construction and subsequent operation cheaper.

Grain storage (towers) are built in groups of, for example, 6-8 structures. Grouping simplifies the construction process, including planning, financing, land acquisition (legal issues), supplying electricity to one site, providing roads to bring materials. Also, the deployment of labor (builders) for the construction of the complex, etc. is solved once.

Grouping facilitates the process of further *organizational and technical* operation of the complex, including: protection of the territory, maintenance of electrical power supply equipment, regulatory maintenance and running repairs of equipment and machinery, etc. Grouping of granaries (towers) into complexes solves (simplifies) also many issues of the following *target* operation of granaries: delivery - pre-processing - storage - export of grain, organization of control of the stored grain material, preventive and remedial measures to maintain the stored material in condition, etc.

In organizational-operational terms, in the aspect of *digitalization* of the operation process (implementation and maintenance of appropriate software), including the drafting of this sketch model, the grouping of individual granaries (towers) is convenient as follows.

1. Erection of granaries (towers) is carried out simultaneously or in close time. This is due to the need to concentrate labor and construction equipment. But at the same time, the towers themselves and all the equipment are in approximately the same state of readiness (operational deterioration). The component equipment of the towers is also delivered and installed simultaneously or at close dates and mostly by the same specialists (builders, installers of equipment). Therefore, it is just as uniform and equally worn.

2. The area of placement of granaries is usually compact, because it is associated with problems of land acquisition, economical use of resources, etc., including the protection of the territory. Therefore, individual granary towers are not far from each other. Therefore, we can assume that all buildings are in the same natural environment: illumination (heating) by the sun, blowing

(cooling) by winds, exposure to precipitation, the risk of power supply failures due to natural disasters, etc.

3. In the process of *target* operation (actually, work with grain), the entire granary complex in terms of organization and in terms of software (computer support), can be under unified management. Hence, we can speak of the unity (identity) of the approaches to the problem of grain storage for each tower.

In view of the above-mentioned, when compiling the model, it is possible (perhaps with certain reservations) to speak about the *identity* of granaries (towers) and the *equivalence* (similarity) of the condition and storage conditions of grain in them.

Quality model description

Creating a model involves formalizing the description. The basis of formalization can be configuration concepts of the modelled object, the characteristics of the object itself, as well as external influencing factors. According to the totality of these attributes of the description, the processes occurring in the object are considered (studied, conceptually assumed). It is assumed that the model should take into account (describe, cover) the course (mutual influence) of these processes, taking into account the interaction of configuration and external influencing factors (Fig. 1).

The purpose of the model is to organize and consolidate knowledge about the object, also (ideally) to implement predictive and instructive functions.

Knowledge Arrangement. It should be based on the incompleteness of the available information about the object. A model (the existence of a model) implies the possibility of replenishing, supplementing and modifying knowledge (perceptions) about the object being modeled. The model should be adaptable (configurable, reconfigurable, adjustable) in relation to the object, and ideally learning and self-learning.

Predictive functions. With the use of the model, it should be possible to describe the behavior of the object (the course of processes in the object) in some (defined, specified) future.

Instructional Function. With the use of predictive functions (foresight functions) of the model, it should be possible to produce recommendations to actively change the processes taking place, in order to maintain the simulated object in a particular defined state. We are talking about using the model as the basis for an expert system (decision support system) to control the object. Consider the following factors affecting the organization of remote control (Fig. 2).

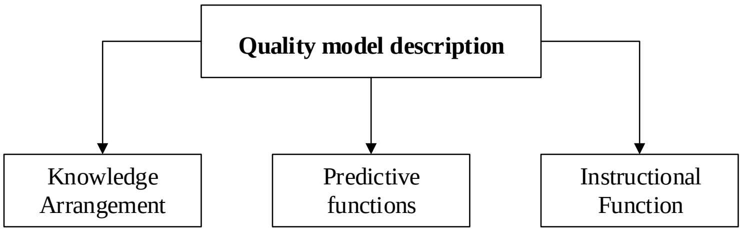

Fig. 1. Quality model description

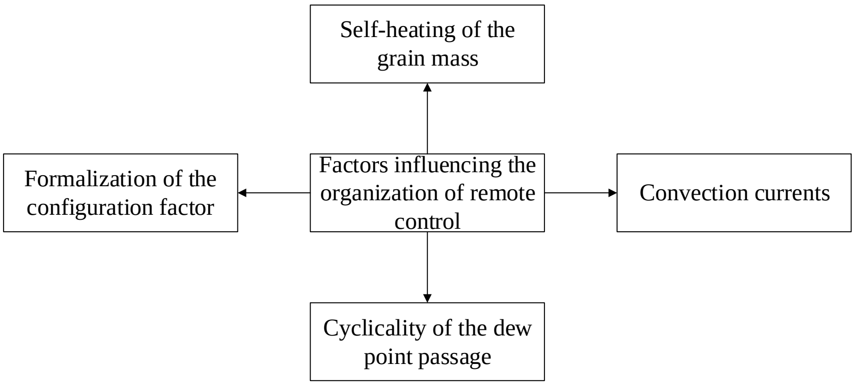

Fig. 2. Factors influencing the organization of remote control

These include: formalization of the configuration factor, self-heating of the grain mass, convection currents, cyclicality of the dew point passage.

Formalization of the configuration factor

The currently accepted (widespread) form of building a granary is a straight circular cylinder. Filling and extraction of grit material is done from above, in the direction of the cylinder axis. The construction advantage of this solution is the minimum material cost: the maximum volume for a given amount of used building material (sheet metal). The technological advantage is the use of sheet material (metal sheet), bent along the cylindrical formation. Of course, geometrically, the spherical shape of the granary would be even more profitable in terms of material/volume ratio. Sphere - limits the maximum volume for a given fixed surface area. But the *non-planarity* (non-reducibility to a flat sheet material) of the structural elements - sphere segments - significantly increases the cost of such a design solution.

The operational advantage of the cylindrical shape of the granary is the absence of corners (axisymmetry). This ensures uniform distribution of stored material (grain) in all directions during axial loading (backfilling). Consequently, there are no "special places" that create difficulties in the removal of stored material (grain).

Since the shape of the tower is a straight circular cylinder, it is natural to use a cylindrical coordinate system to describe the inner volume: (H, R, α) - height, radius, angle of rotation of the plane (H, R). It is reasonable to consider (in a model approximation) the product storage conditions in the storage volume as axisymmetric. According to the conditions of filling the product in the storage, there is no fundamental reason to single out any of the directions in terms of α angle. In this regard, in the future, only two parameters can be used in the model to indicate a point of space inside the volume: (H, R) - height and radius. The two-parameter description (H, R) means that the layout (filling) of the material (grain) inside the storage can be characterized by two factors: layering (belonging to some layer along the height of the cylinder) and the radius distance from the central axis. This means that some point (a small volume of stored product or a place where the i-th sensor of the measuring equipment system can be placed) is characterized by a pair of coordinates (h_i, r_i) according to its location inside the cylinder.

This also means that various sensors located in different places in the thickness of the stored product and generally control the state of the product through the volume of the storage, within the model can be correlated with the coordinates on the plane (H, R), and with a quarter of the plane with positive values of the coordinates: $h_i, \in (0, H_0)$, $r_i \in (0, R_0)$, where H_0 and R_0 are the height and half-diameter of the storage tower, respectively.

Besides, in view of initially assumed (postulated within the model) identity of towers and identity of grain storage conditions in them (see above), coordinates of sensors in all granaries of this group of towers can be correlated with the same model plane (H, R).

Cyclicality of the dew point passage

The most important factors influencing the stored grain product and, accordingly, the factors characterizing the state of the stored grain product are temperature T and humidity P. The complexity consists in the fact that these factors are interrelated and significantly produced by the external environment.

There is some H_2O in the air all the time. The air can be "wet" or "dry". There is a limit value for the concentration of H_2O in the air for a given temperature value. When this concentration is exceeded, H_2O is released from the air in the form of fog or dew fall. There is a concept of "dew point" - the temperature t_0 at which some concentration p_0 of H_2O in the air is the limit. When p_0 is fixed, at $t < t_0$ the dew falls out - excess moisture is released from the air and settles on objects. At $t > t_0$ the dew dries out - is absorbed by the air. The process looks like it is reversible. But in the case of loose substances, including grain in the granary, the reversibility is not complete. The dew that falls at $t < t_0$ is partially absorbed by the grain. Consequently, at $t > t0$, moisture enters the air mass inside the granary (absorbed by the air inside the granary) partially from outside, from the external atmospheric air, from the environment. Result: With cyclic temperature changes around the dew point, the grain mass accumulates moisture. This phenomenon is really observed. The cyclicity of temperature changes is ensured by the change of day and night, and the presence of excess moisture in the outer atmospheric air by meteorological phenomena and seasonal climatic changes, ("rainy weather"). At the same time, the humidity of the grain mass increases (accumulates). Exceeding the permissible norms has a negative impact on the quality of the stored product.

Convection currents

Another important factor (feature) of grain storage is the emergence of convection currents. Due to the radial temperature gradient of the grain mass, convergent and divergent air flows through the grain mass take place (automatically occur)[4]. The formation and directionality of air currents is determined by seasonality. Grain is usually stored in the late summer to early fall season. Grain storage is done in fast time. Therefore, initially the temperature of the grain mass over the volume of the granary is homogeneous. Then, during storage, the temperature change goes from the periphery to the center.

When cold weather arrives, the walls of the granary are cooled. First, the peripheral part of the grain mass is cooled - along the walls of the cylinder. Then the temperature decrease gradually spreads to the center - to the axis of the cylinder. In general, the average temperature of the grain mass (all the grain in the storage) - decreases. But the central (axial) part of the stored cools down more slowly. The result - the emergence of convection heat air flows inside the grain mass. Cold air flows down into the area along the walls of the cylinder; warm air rises up along the axis of the cylinder. The volume is confined and closed, so the flows are closed. The warm air comes in contact with the dome of the granary, cools and flows down into the area along the walls of the cylinder etc. Warm air along the central axial direction carries moisture to the upper layers. There the air is cooled, the moisture condenses, and the upper layers are humidified. Thus, in the upper part of the granary a zone of high humidity of the stored product is formed.

Further, during warming, the grain mass is heated from the periphery to the center. In this case, the direction of the general convection flow (circulation of the air mass through the thickness of the stored product) is inverted. The upward convection warm air flow at the walls of the storage is generated. The central axial flow inside the grain mass is cooler and directed downward. The average temperature of the grain mass slowly rises. But the cold air along the central axial flow transports moisture to the lower layers. There, the moisture condenses, and the lower layers become moist. In this case, now in the lower part of the granary is formed zone of increased humidity of the stored product.

Additionally, the seasonal processes of the formation of convective air currents are superimposed on the diurnal processes of temperature fluctuations near the "dew point". The result is a layered structure in the distribution of moisture in the grain mass.

Self-heating of the grain mass

Another point related to grain storage is self-heating of grain [5]. Grain (each grain individually) is a biological object. Consequently, metabolic processes inherent to the entire living environment take place in grains. Metabolism is activated under some (not always reliably diagnosed) combination of temperature and humidity factors. The process initially develops slowly, but then goes at an increasing rate, about 0.05 ^{0}C / day. The result is self-heating of the thickness of the grain mass up to +35^{0}C. Thus, the effect of self-heating can be commensurate in importance with the effects of external (seasonal and daily) temperature and humidity influencing factors.

Conceptual view of the dependencies T(h, r) and P(h, r)

Daily and seasonal temperature-humidity changes with the imposition of self-heating mode of grain mass create a complex time-varying pattern of temperature and humidity distribution, in the thickness of the grain mass. Within the axisymmetric model under consideration, the description of the current state is reduced to a pair of surfaces - graphs of dependencies on two variables: T(h, r) and P(h, r).

In qualitative terms, the temperature dependences T(h, r) look like planes of complex shape with decreasing in the radial direction from the axis to the cylinder form. In the case of predominance of the seasonal component of temperature changes - the surface looks monotonically along the axis H (along the height of the cylinder). When the component related to self-heating dominates, a smoothly decreasing maximum is localized near the H-axis (i.e., a local heating area is seen in the center of the mass volume of the stored product).

The moisture dependences P(h, r), in qualitative terms, look the same with a smooth decrease in the radial direction (from the axis to the cylinder walls), but less uniform in the height of the cylinder (along the axis H). This is due to the preferential axial centering of the moistening area of the product and the above described transfer of the moistening area in accordance with the seasonal and diurnal temperature changes near the "dew point". The result is a "wave" on the surface P(h, r) at the top during the seasonal temperature drop; and a similar "wave" at the bottom during the seasonal storage temperature rise phase.

The specific type of surface graphs is determined by the specific initial conditions: it depends both on the geometrical parameters of a particular granary and on the storage object and the adopted storage mode. In addition, the specific phase of storage is essential. Grain mass, of course, "shows different behavior" immediately after filling, after some time, when the internal temperature-humidity balance is established, or at the end of the storage period, with already formed and possibly shifted areas of local moisture and (or) warming. Moreover, under certain external (atmospheric) temperature-humidity conditions, the factors of self-heating and the area of local humidification can mutually influence and, accordingly, deform (modify) the configuration of the graph surfaces T(h, r) and P(h, r). As follows from the consideration, the dependences T(h, r) and P(h, r), taken separately, mostly do not characterize the overall picture of grain storage. But T(h, r) and P(h, r) together can be more unambiguous in interpretation and can be applied to adjusting, calibrating, and training models up to the realization of predictive and recommender functions.

For the qualitative construction of the profiles T(h, r) and P(h, r) actually corresponding to specific situations of grain storage, there are (by now accumulated) extensive data, because, as noted, grain handling techniques have been an essential element of traditional common human culture since the late Neolithic. At the same time, technology and equipment are constantly being improved, in this regard, applied research is constantly carried out. As a result, in relation to the considered cylindrical tower-type granaries, there are generalized qualitative ideas about the nature of the distribution of values of key parameters. On a constant basis systems of sensors are used, which are located in the thickness of the grain layer. Thus, in the system described in [5], a bundle of 6 sensors in the vertical direction with a spacing of 5 m is used in 30-meter tower-type storages.

Sensors allow current control of distribution profiles T(h, r) and P(h, r). And the totality of the results for the whole cycle of product storage is an objective time profile of the whole storage process.

Thus, with respect to the developed model, in principle, a set of distribution profiles T(h, r) and P(h, r) can be obtained, which can be used for calibration, training or learning (depending on the direction of development) of the software part of the system.

Modified Kohonen Maps

The model described at the qualitative level allows us to follow the development of the situation up to the prediction of possible next states and decision making. It is of interest to study the elements of the intellectual part of the system - prediction of the situation development and decision making. To achieve this, it is necessary to propose (consider) options for organizing the actual remote control in terms of processing algorithms, i.e., consider possible adaptive procedures for information processing.

The situation under consideration is quite complex. The data are known in fragments. In particular, only individual irregularly located points are available for the construction of surfaces. It can be about approximation, probabilistic interpretation, a problem like pattern recognition, identification of situations. An acceptable variant of the solution is the Kohonen maps. Moreover, the modified version [2, 3] is interesting, as it is more economical in calculations.

This version of the neural network is based on the principle of "learning without a teacher".

The network is trained to identify elements (states) by evaluating the degree of proximity or finding differences between them. After a period of training, the network will be able to classify states and assign a particular realization to one of its distinguishable classes.

The presented implementation can be a set of parameter values, and the recognized class can be a recommended solution variant for a given set of parameters.

The main advantage of this toolkit is the ability to significantly reduce the dimensionality of the system.

The input set of parameters can be multidimensional, and the chosen solution can be one of a linear series of values.

Three-level conditions identification system

In the subject area under consideration - observation and making decisions on the process of grain storage - at least three levels of informativeness of observation of states can be distinguished. Each of the levels is characterized by its structure and importance for decision-making (Fig. 3).

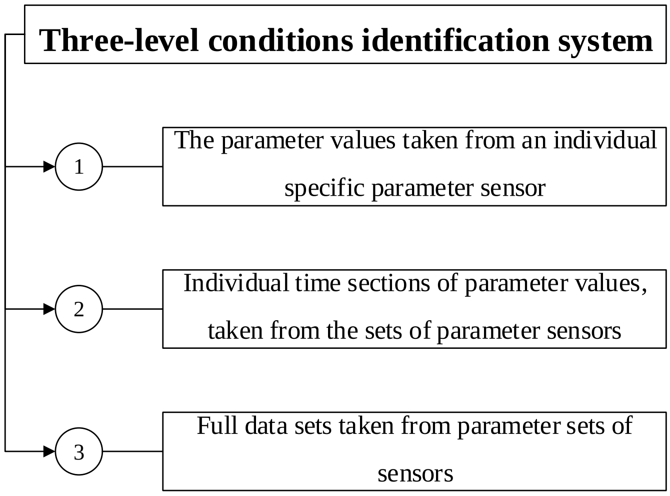

Fig. 3. Three-level conditions identification system

The first level is the parameter values taken from an individual specific parameter sensor. Grain storage assumes that there are sets of parameter sensors T and P. Each of the sensors gives out individual values of parameters in the corresponding point of the volume of the granary. Information from this individual sensor - by itself - is not very informative to describe the state of the granary. But it is interesting for evaluation of individual features of the sensor. A sharp difference between the readings of this sensor and the others suggests sensor failure. Further it can be excluded from consideration. A slight systematic difference in the sensor readings from several neighboring sensors may indicate a calibration failure. A correction for such a sensor can be introduced in the future. Of course, there should not be too many sensors that are out of calibration and/or out of order, and this should be certified for a given sensor system before the grain store is loaded.

The second level - individual time sections of parameter values, taken from the sets of parameter sensors. We are talking about synchronously taken data sets over the entire granary. The time sections give a view of the current state. This view may not be very informative from the point of view of long-term storage. But this view can be important in extreme cases. Example. A sudden, localized increase in humidity at the top of a grain store can be a signal that the roof is leaking and needs to be repaired urgently.

The third level is full data sets taken from parameter sets of sensors. Change of values of parameters T and P occurs in time. The set of time sections gives a picture of gradation of states for a certain period of time, i.e. demonstrates the dynamics of change of states. This information is complete and comprehensive for a given cycle of grain storage, from loading to unloading. It can reflect, in particular, the entire cyclicity of the emergence and movement of local areas of grain moisture. It can also be used to trace and independently assess the conditionality of grain - compliance with the required standards throughout the storage cycle. But most importantly, this information of the third level is a complete protocol of this storage cycle, which is valuable in the aspect of accumulation of experience for subsequent storage cycles.

Discussion

1. Obviously, there is a theoretical-multiple relation of nesting between the information sets of these three levels of awareness. The second level is the time sections of the third level, and the first level is the section of the second level by individual sensors. Thus, all information must be captured, and the level of its subsequent processing is a matter of processing procedure. I.e., the division into three levels is just a methodological approach for singling out the individual components of the processing of the total unified array of information, convenient in the lan of analysis of the organization of the structure of subsequent processing.

2. For each of the three levels of awareness considered, a separate processing procedure can be performed using the Kohonen map toolkit [2]. For this

purpose, a training sample can be organized for each of the levels, on which the neural network will be trained. Certainly, for these three levels, each next level works with sample volumes at least an order of magnitude larger than the previous one. Accordingly, the volumes of training samples and the times (duration of procedures) of training must differ by at least two orders of magnitude.

3. Another option (perhaps more interesting) is to use the "output product" of each next level as "input data" for the next. Example. Individual numerical values - individual sensor readings on the first level can be recognized as "normal", "dangerous" or "critically dangerous". Individual combinations of sensor readings taken from the first level results can be evaluated at the second level as "normal", "moisture formation from above", "...in the center", etc. Similarly, separate combinations of indicators taken from the identified situations of the second level can be recognized on the third level as "movement of moistening area upwards", "...downwards", "expansion of moistening area", "reduction...", etc. Probably, in this case the volumes of training samples and training procedures will be correspondingly reduced. But perhaps the whole procedure for building such a system will become more complicated, due to the introduction of interconnections between the relatively autonomous procedures of the first, second and third levels separately.

4. The above (items 2 and 3) refers only to the procedures of using the Kohonen Maps toolkit, which provides pattern recognition and state identification. Recommendations on decision-making are the competence of specialists in the applied field - grain storage. Therefore, transforming the work of the Kohonen map toolkit into meaningful recommendations - the development and operation of an appropriate expert system may be a subject for separate consideration.

5. The fourth level of information - generalization (consolidation) of information of the third level - combining the experience of several consecutive cycles (several years) of using the granary of this type was outlined above, but not specified. This fourth level may include (take into account) the effect of wear and tear of individual elements of granary equipment, individual facts of repair and modernization of equipment, individual facts of violation of the mode of operation, etc. The "output product" of this fourth level of awareness can be the development of recommendations for the modernization of equipment and methods of organizing the storage of grain material.

Conclusion

1. A schematic qualitative description of the typical stages and basic processes of grain products storage is presented.

2. A variant of formalization of the model for the two-parameter case of information description of the state of the stored grain product is considered.

3. The concept of a model three-level system of organization of information processes in relation to the remote quality control of the preservation of grain products is considered.

4. The variants of realization of basic elements of information quality control of grain products storage were discussed.

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Інтелектуальні підходи до організації видаленого контролю якості зберігання зернових продуктів

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Анотація. Зернові - значна частина поживного раціону типу Homo sapiens. З часів пізнього неоліту, з переходом на осіле землеробство, робота із зерном (вирощування, зберігання, переробка, приготування харчових продуктів) стала традиційним видом професійної людської діяльності. В рамках накопиченого історичного досвіду, за цим видом діяльності було розроблено та оптимізовано численні технологічні процеси. Відповідні технології розвивалися у зв'язку зі зміною життєвих потреб, буквально під тиском Дарвінівського природного відбору, оскільки були безпосередньо пов'язані з виживанням виду Homo sapiens. Подальший розвиток технологій зернообробки залишається незмінно актуальним і донині, на підтвердження чого – доповідь [1], подана ООН, про стан продовольчої безпеки та харчування у світі – з жахливими цифрами, що зображують потребу та лиха широких народних мас населення планети. Важливою складовою зернообробки є технології, пов'язані із зберіганням зернопродуктів. Частина зернопродуктів, що зберігаються, використовується як насіннєвий фонд для нового циклу реалізації зернозабезпечення, інша – істотна – для переробки в харчові продукти. При цьому нові технології зернозберігання, що розробляються (оптимізуються, удосконалюються), повинні бути безпечними, маловитратними, максимально сумісними з розробленим раніше обладнанням, масштабованими на великі обсяги матеріалу, що зберігається. Зрозуміло, що технології повинні забезпечувати належну ефективність, показником чого має бути зниження відсотка втрат зернопродукту. У цьому відношенні суттєво важливі методи управління, які застосовуються в рамках технологічних процесів зберігання зернопродуктів, а також методи контролю за поточним станом зернопродуктів для коректної організації роботи технологічних процесів. Цікавими, зокрема, є методи з використанням елементів штучного інтелекту. У тому числі, перспективні нейронні мережі, особливо здатні до навчання «без вчителя» - карти Кохонена (КК). Модифікований алгоритм КК [2] реалізує скорочений час навчання [3], що є актуальним при реалізації адаптивних процедур обробки результатів вимірювань контрольованих параметрів. **Мета цієї роботи** – розгляд принципів використання модифікованих карт Кохонена для класифікації ситуацій стосовно дистанційного контролю якості зберігання зернових продуктів.

Ключові слова: зерно, карти Кохонена, система ідентифікації умов, енергозбереження.

Интеллектуальные подходы к организации удаленного контроля качества хранения зерновых продуктов

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Аннотация. Зерновые – существенная часть питательного рациона вида Homo sapiens. Со времён позднего неолита, с переходом на оседлое земледелие, работа с зерном (выращивание, хранение, переработка, приготовление пищевых продуктов) стала традиционным видом профессиональной человеческой деятельности. В рамках накопленного исторического опыта, по данному виду деятельности были разработаны и оптимизированы многочисленные технологические процессы. Соответствующие технологии развивались в тесной связи с изменением жизненных потребностей, буквально под давлением Дарвиновского естественного отбора, поскольку были непосредственно связаны с выживанием вида Homo sapiens. Дальнейшее развитие технологий зернообработки остаётся неизменно актуальным и по сей день, в подтверждение чего – доклад [1], представленный ООН, о состояние продовольственной безопасности и питания в мире – с ужасающими цифрами, изображающими нужду и бедствия широких народных масс населения планеты. Важной составляющей зернообработки являются технологии, связанные с хранением зернопродуктов. Часть хранимых зернопродуктов используется в качестве семенного фонда для нового цикла реализации зернообеспечения, другая – существенная – для переработки в пищевые продукты. При этом, вновь разрабатываемые (оптимизируемые, совершенствуемые) технологии зернохранения должны быть безопасными, малозатратными, максимально совместимыми с разработанным ранее (имеющимся в наличии) оборудованием, масштабируемыми на большие объёмы хранимого материала. Разумеется, технологии должны обеспечивать надлежащую эффективность, показателем чего должно являться снижение процента потерь зернопродукта. В этом отношении существенно важны методы управления, применяемые в рамках технологических процессов хранения зернопродуктов, а также методы контроля за текущим состоянием зернопродуктов для корректной организации работы технологических процессов. Интересны, в частности, методы с использованием элементов искусственного интеллекта. Среди них, перспективны нейронные сети, в особенности способные к обучению «без учителя» - карты Кохонена (КК). Модифицированный алгоритм КК [2] реализует сокращённое время обучения [3], что актуально при реализации адаптивных процедур обработки результатов измерений контролируемых параметров. **Цель настоящей работы** – рассмотрение принципов использования модифицированных карт Кохонена для классификации ситуаций применительно к дистанционному контролю качества хранения зерновых продуктов.

Ключевые слова: зерно, карты Кохонена, система идентификации условий, энергосбережение.