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USE OF GEOSTATIC FUNCTION TO DESCRIBE WHEAT GRAIN MASS QUALITY

Summary

Examination of quality factors for agricultural and food products becomes more and more important because of their suitability for further processing and trade turnover. Independently of processing, agricultural and food industry is also expected to provide suitable protection for raw vegetable products generally characterised by inferior durability, and their processing into safe and durable food products, while maintaining proper taste quality. Computerised image analysis, neural modelling, and use of artificial intelligence methods have enormous future also in the fields of food industry and agriculture. Development of fast and efficient method is very much justified, since it will allow making accurate and quick observations without using any additional complex laboratory methods.
***Key words**: image analysis, quality, function geostatic, wheat*

ZASTOSOWANIE FUNKCJI GEOSTATYCZNEJ DO OPISU JAKOŚCI MASY ZIARNA PSZENICY

Streszczenie

Badanie cech jakościowych produktów rolno-spożywczych ma coraz większe znaczenie ze względu na przydatność ich do dalszej przeróbki i obrotu handlowego. Zadaniem przemysłu rolno-spożywczego jest oprócz przetwórstwa także właściwe zabezpieczenie, na ogół mało trwałych surowców roślinnych oraz ich przetworzenie w bezpieczne i trwałe produkty spożywcze – z zachowaniem ich odpowiednich walorów smakowych. Komputerowa analiza obrazu, modelowanie neuronowe, wykorzystywanie metod sztucznej inteligencji ma ogromną przyszłość również w dziedzinie przemysłu spożywczego i rolnictwa. Opracowanie szybkiej i skutecznej metody jest jak najbardziej uzasadnione, gdyż to pozwoli na dokonywanie trafnych i szybkich obserwacji, bez używania dodatkowo skomplikowanych metod laboratoryjnych.
***Słowa kluczowe**: funkcja geostatyczna, komputerowa analiza obrazu, akwizycja obrazu, modelowanie neuronowe*

1. Introduction

Agricultural and food products and raw materials are characterised by adequate colour and shape – easy to recognise features. Using digital photos of the studied products, we may determine in an objectivized way e.g. colour - in many cases a leading feature, which proves raw material or product quality [5] Colour is one of the basic physical properties, which decide about attractiveness of raw materials and products. It applies both to external and internal appearance. In the sensory meaning, each human being has slightly different colour perception. This is due to the fact that visual memory is very poor compared to aural memory and it limits memorising of colours. Another difficulty in colour description is the fact that colour perception is affected by incident light. The term "image recognition" is some kind of commonly used shortening. Precise expression should be: "automatic defining of physical objects attribution to predetermined abstraction classes on the basis of their images" [9]. According to Tadeusiewicz [8], it is possible to perform many useful transformations on images, intended to improve information contained in an image. In their studies, Koszela, Boniecki and Weres [4] employed many morphological transformations allowing highlighting shape features of cut vegetables. The main concept of this method concerns specifying the volume of suitable dried vegetable fractions in the examined sample, regarding their shape and colour.

2. Work purpose and scope

The purpose of the work was to develop an innovative method for modelling the process of farm produce quality assessment on the basis of computerised image analysis and artificial neural networks (ANN).

Therefore, it has been assumed that the developed application for processing and analysis of acquired digital images, based on the *RGB* colour recognition model, will allow obtaining quick and good method for product quality assessment. There is high practical demand for solutions of this sort, e.g. while purchasing crops to stores [1]. Determined preliminary quality of accepted seeds as regards their fouling/impurity content gives an immediate basis for establishing the price for purchased material. Another aspect of using this method is quality control for grain kept in stores [2]. Development of such method will allow obtaining results quickly, omitting time-consuming laboratory works.

For this purpose, the scope of works has been divided as follows:
- preparing wheat seeds samples,
- preparing and developing a computer application for the evaluation of grain mass fouling level based on the *RGB* model,
- preparing a measurement setup to allow making digital photographs of suitable quality,
- making digital photographs of taken wheat seed samples,
- analysing photographs of wheat seed samples, obtained and converted to the "bmp" format using the "APR" computer application, and further conversion to binary form,
- tabular comparison of decimal-to-binary conversion results ("1"; "0"),
- neural analysis,
- geostatics.

In order to recognise and solve the above-mentioned problems, the researchers developed an innovative method for computerised image analysis, and employed artificial neural networks, which allowed carrying out quick and precise evaluation. For this purpose, they developed a method to take samples for tests and to make digital photographs in an appropriate way, so as to obtain the required information.

3. Research methodology

Few series of tests were completed during the experiment. The experiment involved examining granular material fouling level. Wheat seeds obtained from "Opole Port" elevator were used for tests.

A test stand for computerised image acquisition has been made in order to determine grain mass purity. The stand has been provided with suitable light sources. The stand consists of the following components:

- web cam, digital camera,
- computer acquiring and processing data,
- backlit table, on which the examined samples are placed,
- software allowing cam image monitoring and ensuring possibility to make photographs (Fig. 1).

Due to the need to maintain repeatability of measurements, side walls were made of light diffusing material. Internal lamps were the main light source. It is important to ensure that external lighting is not intense and does not fall onto the setup side walls concentrated in single spot(s).

The second stage of the research involved development of a computer application for the examined material quality assessment and neural analysis of obtained results.

The APR (Analyses Processing Recognition) application has been used for image analysis, processing and recognition. Its basic feature is the possibility to build image processing scripts. A script language has been built in for this purpose, which allows carrying out whole range of graphical operations. Moreover, it is possible to enter commands directly in the command line. Some operations are available from the panel containing an appropriate interface for communication with user. Basic elements of the interface with user consist of three basic windows: main, video and scripts.

Wheat grain from "Opole-Port" corn elevator was used in the examinations. The researchers performed a series of purity evaluation tests for grain fruit-seed cover in order to examine fungi spore occurrence. The tests were carried out for 21 days, in a chamber, where grain was not ventilated. Every day grain samples were taken, from which the researchers were separating 50g samples for the analysis. The examination involved visual check of changes on fruit-seed cover - seeds were observed under a microscope, and then visual impressions were noted in the table (Tab. 1). Fouling level was assessed on the basis of fruit-seed cover external appearance. At the same time, digital camera was used to make a photograph of adequately prepared grain sample, and fruit-seed cover purity was evaluated with the "APR" computer application.

A digital camera was used to make photographs and for framing - photograph surface area selected for analysis was marked and saved in the "bmp" format. Then, they were converted into black-and-white images using graphical application.

Subsequently, they were subject to digitising for arbitrarily determined test window resolution (30 x 30 = 900 pixels) (Fig. 2a).

Depending on obtained grey level for individual window pixels, they were subjected to decimal-to-binary conversion into impurities and "background" (in binary notation marked "1" and "0", respectively). The results of decimal-to-binary conversion for individual photographs were compiled in tabular form for the next stage of computations carried out using neural network (Fig. 2b).

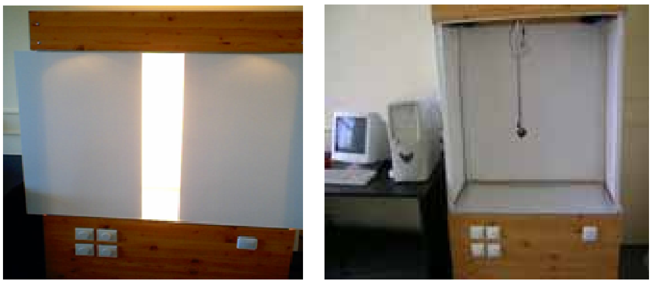

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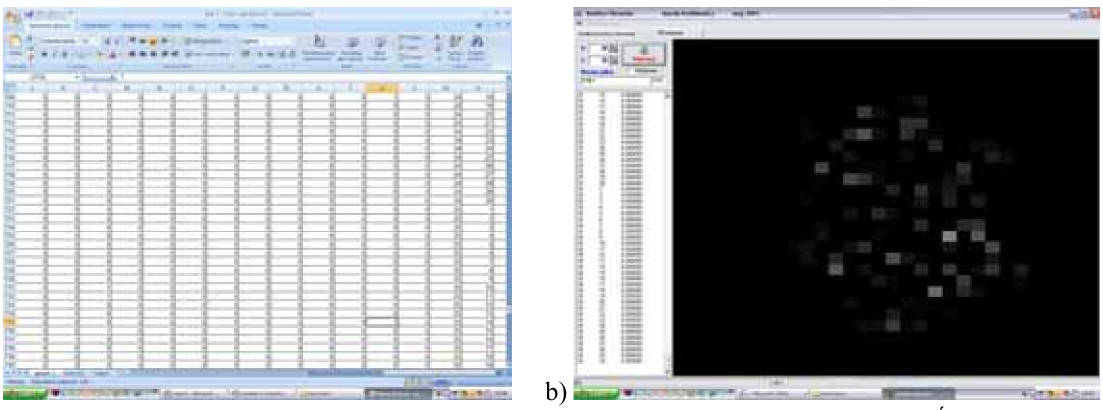
Fig. 1. General view of basic module of a setup for computerised image acquisition
Rys. 1. Ogólny widok modułu podstawowego stanowiska do komputerowej akwizycji obrazu



a) b)

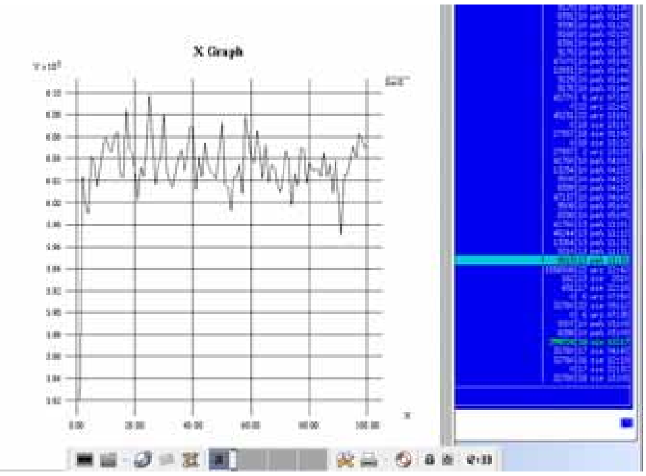
Source: own study / Źródło:opracowanie własne

Fig. 2. a) Image after pixellisation: 30x30 cells; b) comparison of obtained results after pixellisation
Rys. 2. a) Obraz po pikselizacji: 30x30 komórek; b) zestawienie uzyskanych wyników po pikselizacji

Table 1. Visual changes on wheat fruit-seed cover during storage
Tab. 1. Wizualne zmiany na okrywie owocowo-nasiennej pszenicy w czasie magazynowania

Pos.	Grain mass temperature [°C]	Humidity of grain mass during storage [%]	Specification of microscope observation	Results of pure grain observation carried out using the “APR” application
1	13.6	14.5	Pure grain, no visible water drops	99.7
2	13.8	14.5	Pure grain, no changes on fruit-seed cover of seeds	99.3
3	13.8	14.5	Pure grain, no changes on fruit-seed cover of seeds	99.2
4	13.9	14.5	Pure grain, no changes on fruit-seed cover of seeds	99.2
5	14.1	14.5	Pure grain, no changes on fruit-seed cover of seeds	99
6	14.3	14.5	Pure grain, no changes on fruit-seed cover of seeds	99
7	14.3	14.5	Pure grain, no changes on fruit-seed cover of seeds	99.1
8	14.3	14.5	Pure grain, no changes on fruit-seed cover of seeds	99.1
9	14.4	15	Pure grain, visible single water drops on fruit-seed cover of seeds	90.8
10	14.6	15	Pure grain, visible single water drops on fruit-seed cover of seeds	87.9
11	14.8	15	Pure grain, visible single water drops on fruit-seed cover of seeds	84.5
12	14.9	15	Pure grain, visible single water drops on fruit-seed cover of seeds	80.2
13	15.1	15.5	Pure grain, visible single water drops on fruit-seed cover of seeds	80.2
14	15.5	15.5	Single black spots on fruit-seed cover, visible water drops	75.6
15	15.9	15.5	Single black spots, water drops	75.0
16	16.1	15.5	Concentrations of black spots on fruit-seed cover	70.3
17	16.2	15.5	Very distinct concentrations of black spots	70.2
18	16.4	15.5	Very distinct concentrations of black spots	70.3
19	16.6	15.5	Very distinct concentrations of black spots	70
20	16.7	15.5	Single fungus blooms, musty smell	70
21	16.8	15.5	Fruit-seed cover to a large extent covered with mildew	70

Source: own study / Źródło:opracowanie własne



Source: own study upon [6] / Źródło:opracowanie własne na podstawie [6]

Fig. 3. Selected numerical and graphical neural network learning parameters in the Flexible Bayesian Models application
Rys. 3. Wybrane liczbowe i graficzne parametry uczenia się sieci neuronowej w programie Flexible Bayesian Models

Neural analysis was carried out in a package Flexible Bayesian Models on Neural Networks [6]. Adequately selected neural network architecture was assumed in the accepted regressive model. In order to specify the most frequently “represented” locations of the examined impurities in individual groups, coordinates of points (dependent variables – *targets*) were juxtaposed to binary variables (independent – *inputs*). The number of independent variables in each group for each impurity type was determined by the number of binary images approved for this analysis – that is with point fraction not exceeding 10% of the whole set of points in the test window – that is approximately 90 points of impurities. Arbitrarily chosen image acceptance level was justified by the fear of possible blur of impurities and background in case of photographs with too much dim (the most “clear-cut” photographs were analysed).

The number of hidden layers was being established at the level allowing most efficient network learning, monitored with the so-called rejection rate, hyperparameters and their diagrams. Numerical simulation was carried out for 100 steps of iteration, after having rejected the first 20% starting steps (the so-called burn-ins) (fig. 3).

4. Analysis and discussion of results

A non-parametric Kolmogorow-Smirnow test was used to assess consistence of a given point distribution. It allowed estimating observed spatial locations of points in the test window and comparing them to expected values. Statistics in Kolmogorow-Smirnow test is as follows:

$$D_{n1,n2} = max[F_{n1}(x)-F_{n2}(x)] \quad (1)$$

where: $F_{n1}(x)$ and $F_{n2}(x)$ indicate appropriate empirical cumulative distribution functions for the first and second sample, n1 and n2 are respective sizes of these samples.

Impurity distribution method in grain mass was described using one of geostatic functions – the K-function.

Spatial distribution analysis for observed particles concerns a set of points irregularly distributed in a limited surface area. As we mentioned before, the researchers made an attempt to carry out geostatistic adaptation of K-function for analysis of fouling distribution in grain mass. The properties of spatial distribution of points describing relationships occurring among them are easy to characterise using K-function. K-function is defined as follows:

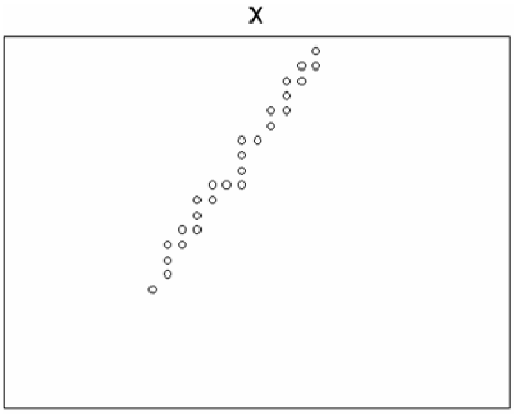
$$K(d) = \lambda - 1E \qquad (2)$$

[number of points ≤ distance d from arbitrarily determined value]
where:
λ – intensity (number of points in area unit),
E – expected value (number of points ≤ distance d from arbitrarily determined value) [3].

Estimator for the above K-function was specified by Ripley [7]. K-function has the following advantage: its theoretical value is known for few useful spatial distribution models. Diagram of function Πd2 may be the example of K-function for homogeneous process without occurrence of spatial relationships among points in space. In case when points are grouping in a certain area, we will expect predominance of events for small distances, and thus K-function(d) will be larger than Πd2 (K(d) > Πd2) determined for homogeneous process. If K-function(d) is smaller than Πd^2 ($K(d) < \Pi d^2$), then points are distributed regularly.

During modelling, the researchers were monitoring network learning parameters so as to obtain rejection rate values for initiation within limits from 0.1 to 0.3, and for production run from 0.2 to 0.8. The element is one of the network parameters indicating correct data modelling. The values of the mentioned rates were 0.2 and 0.4, respectively. Observation of the trajectories of learning hyperparameter diagrams was an additional element determining correctly assumed network algorithm values.

Figures 4-5 show graphically the geostatics for wheat grain quality level.

a) 

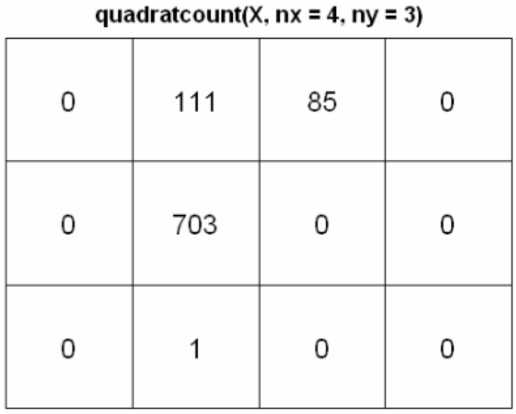
b) 

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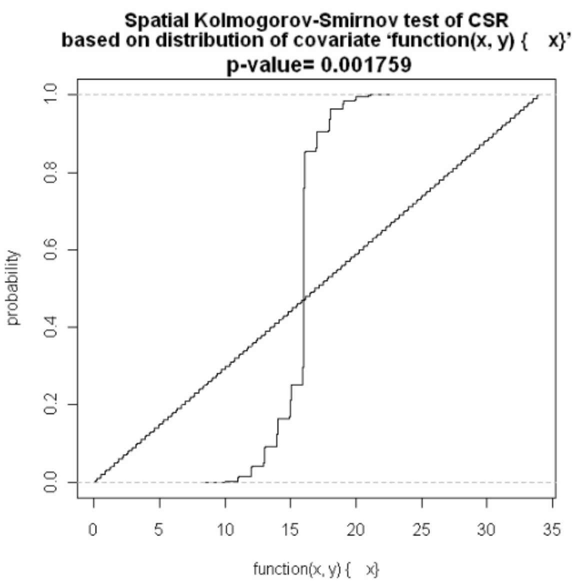
Fig. 4. a) Distribution of impurities in the test window - wheat grain mass, b) Calculation square for distribution of points for impurities in wheat grain mass for nx = 4 and ny = 3

Fig. 4. a) Rozkład zanieczyszczeń w oknie badawczym masie ziarna pszenicy, b) Kwadrat liczenia rozkładu punktów dla zanieczyszczeń w masie ziarna pszenicy dla nx=4 i ny=3

a) 

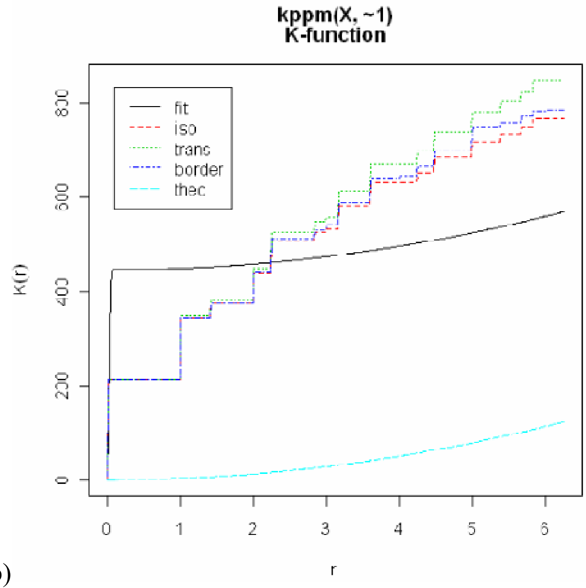
b) 

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Fig. 5. a) Probability diagram for point process scattering for impurities in wheat grain mass, b) K-function diagram for the arrangement of wheat grain and impurities on fruit-seed cover

Fig. 5. a) Wykres prawdopodobieństwa rozproszenia procesu punktowego dla zanieczyszczeń w masie ziarna pszenicy, b) Wykres funkcji K dla układu ziarno pszenicy i zanieczyszczenia na okrywie owocowo-nasiennej

Obtained diagrams and geostatic parameters allow stating that distribution of points in the test window is non-uniform. The following value was obtained for fouling distribution in wheat grain mass: X-square = 59.50 and $p < 2.2e^{-16}$. There are departures from independent arrangement of points, point process centralisation – geostatic interaction exists. There is no basis for rejecting H_0, which indicates lack of geostatic interaction. K-function diagram allows observing strong tendency for concentration of points. On the basis of diagram showing network learning hyperparameters we can say that the model is matched. Model matching is also confirmed by Fig. 6, which shows that function smoothing range (diagram of residuals) is at the level of |1, 2|.

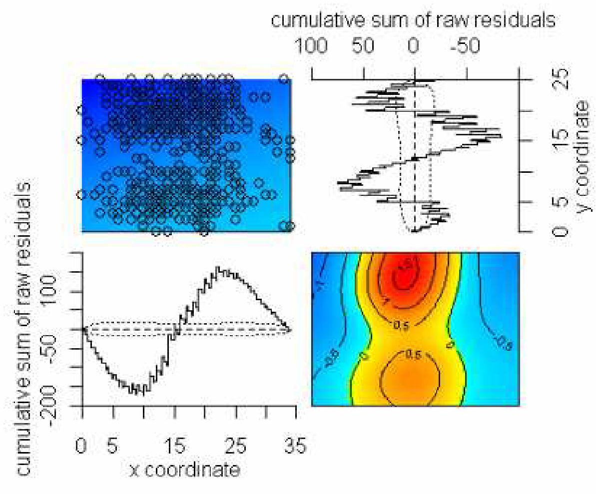

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Fig. 6. Model matching diagram – cumulative sum of raw residuals

Fig. 6. Wykres dopasowania modelu – skumulowana suma pozostałości (reszt)

5. Conclusions

Completed image analysis, neural prediction and geostatic analysis allow stating the following:

1. Generated and logically and empirically verified neural models for the evaluation of fouling distribution in wheat grain have confirmed that it is advisable to use them based on colour characteristics obtained with the developed image analysis software.
2. Employed computerised image analysis made it possible to considerably accelerate the assessment of examined material fouling distribution, compared to conventional methods.
3. The "APR" computer application based on the RGB model recognises colours occurring both in grain mass and fruit-seed cover, which was confirmed during the research.
4. Application of the K-function allowed carrying out observation and statistical identification of regularity of fouling distribution in wheat grain mass.
5. Combination of computerised image analysis, neural analysis and geostatics is an inexpensive and quick method for carrying out analysis of spot character of fouling distribution in wheat grain mass.

Versatility of employed scientific technique in form of combined image analysis and artificial neural networks allows applying it in industrial conditions. A photograph of randomly selected material lot is sufficient to analyse purchased grain fouling state. Definitely, it is possible to reduce analysis execution time and simplify sample taking method. Obtained research results may be used as an important application when solving industrial problems in real conditions.

6. References

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