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NEURAL IDENTIFICATION OF IMAGES SHOWING SELECTED VARIETIES OF STORED POTATOES

Summary

In recent years, there has been a growing interest in the use of modern IT tools in agricultural engineering. Both image analysis methods and artificial neural networks, designed to reproduce the work of the human brain, serve to build predictive and classification models, highly useful for modern agriculture. Correct identification of both the seed material and the produced crops becomes a priority of agricultural engineering, ensuring adequate efficiency and cost-effectiveness of agrotechnical operations. This article presents a project whose aim was to develop an effective neural model for qualitative identification of the variety of stored consumer potato tubers by using input data obtained in the process of digital image analysis. The designed and created artificial neural network model (multilayer perceptron), using informations in the form of selected graphic descriptors, classifies three selected varieties of edible potato (Denar, Gala, Vineta).
***Key words**: artificial neural networks, neural modeling, image analysis, graphic descriptors, edible potato tubers*

NEURONOWA IDENTYFIKACJA OBRAZÓW WYBRANYCH ODMIAN MAGAZYNOWANYCH ZIEMNIAKÓW

Streszczenie

W ostatnich latach dostrzec można wzrastające zainteresowanie wykorzystywaniem nowoczesnych narzędzi informatycznych w inżynierii rolniczej. Zarówno metody analizy obrazu, jak i sztuczne sieci neuronowe, mające odwzorowywać pracę ludzkiego mózgu, służą budowaniu modeli predykcyjnych i klasyfikacyjnych, wysoce użytecznych dla współczesnego rolnictwa. Właściwa identyfikacja zarówno materiału siewnego, jak i wytworzonych plonów, staje się priorytetem inżynierii rolniczej, zapewniając odpowiednią efektywność i opłacalność przeprowadzanych zabiegów agrotechnicznych. Niniejszy artykuł przedstawia projekt, którego celem było opracowanie efektywnego modelu neuronowego służącego do identyfikacji jakościowej odmiany magazynowanych bulw ziemniaków konsumpcyjnych przy użyciu danych wejściowych pozyskanych w procesie analizy obrazów cyfrowych. Zaprojektowany i wytworzony model sztucznej sieci neuronowej (perceptron wielowarstwowy), korzystający z informacji w postaci wybranych deskryptorów graficznych, klasyfikuje trzy wybrane odmiany ziemniaka jadalnego (Denar, Gala, Vineta).
***Słowa kluczowe**: sztuczne sieci neuronowe, modelowanie neuronowe, analiza obrazu, deskryptory graficzne, bulwy ziemniaka jadalnego*

1. Introduction

Over the last decade, one can observe a dynamic development of modern information technologies and innovative methods used in agricultural engineering in Poland. Improvement of production processes in the agri-food sector becomes possible among others thanks to the automation of agrotechnical operations and the increasing use of latest generation IT tools, such as advanced artificial intelligence methods [8]. In the face of growing consumer expectations and the obligation to perform quality control of the crop obtained in line with the legal requirements of the European Union, food producers are obliged to look for pro-ecological solutions not only in the field of production and storage processes, but also proper identification of the collected vegetable material, which allows to minimize losses.

The use of artificial intelligence methods in agricultural engineering becomes a modern and effective way to improve the quality control processes of the obtained biological raw material, replacing the currently used instrumental methods [7]. In the case of agricultural and food production, the selection of an appropriate method to control the quality characteristics of the obtained raw material becomes particularly important. The proper color and shape of food products are factors conditioning not only the proper identification and elimination of crop damage and paralysis, but also decisive factors for the purchase of a given product by a future consumer. Artificial neural networks may provide an alternative to subjective sensory methods or costly quality assessment using a spectrophotometer [1].

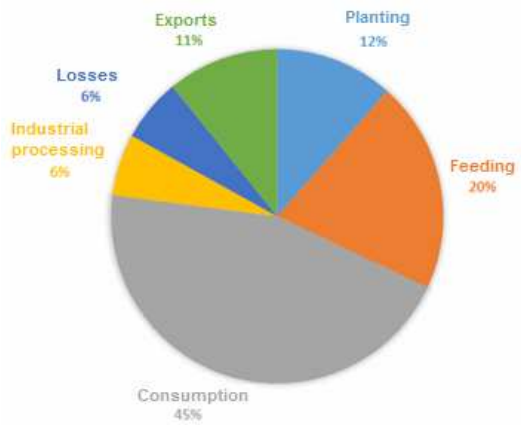
2. The economic importance and culinary values of potatoes

The geographical location of Poland, conditioning the existence of optimum soil and climatic conditions conducive to cultivation of the potato (lat.: *Solanum tuberosum*), makes it the leading producer of this valuable vegetable not only in Europe but also in the world, placing it in tenth place in 2016 global ranking of potato producers. According to data provided by the Central Statistical Office, potato remains the most consumed vegetable, and also a valuable raw material for industrial production. The decreasing area

of potato cultivation in our country is primarily associated with the development of modern agrotechnical methods (mainly fertilization and plant protection) and a gradual decrease in feed use of potato tubers. At the same time, we can notice a systematic increase in the potato yield [2].

In domestic potato cultivation we can distinguish three main directions of use:

a) edible (for direct consumption),
b) used in food processing (crisps, fries, cereals, drought),
c) used in industrial processing (alcohols, starch), among which the use of potato for consumer purposes is definitely predominant.



Source: own study based on CSO data
Źródło: opracowanie własne na podstawie danych GUS

Fig. 1. Potatoes Balance – use 2015/2016
Rys. 1. Bilans ziemniaków – rozchód 2015/2016

Consumer potatoes should have the following physicochemical properties: appropriate size and regular shape, proper color and texture of tubers, no clear mesh, cracks and other mechanical damages, adequate starch content and taste values in accordance with the appropriate culinary type. Therefore, it is crucial for potato producers to meet the expectations of buyers, related to the popularity of a given variety, adaptation of cultivated varieties to the existing local conditions and profitability of production [9].

We distinguish the following culinary types of consumer potatoes:

- A - salad: the structure of the tuber is dense, heat-treated does not break up, it can easily be cut,
- B - general-purpose: the consistency of the tuber is optimally uncluttered, somewhat mealy and moist, low tendency to overcooking,
- C - floury: consistency of the tuber is dense, high propensity to overcooking, it is difficult to be cut, high mealiness and dryness,
- D - very floury: very high tendency to overcooking, very high mealiness, rough structure of the tuber,
- cross types - intermediate types of potatoes (AB, BC, CD) [3].

According to the data of the Central Statistical Office, an average Pole eats about 100 kg of potatoes per year, which makes potatoes the dominant component of the diet of the inhabitants of our country (Table 1). This vegetable is a source of valuable nutrients, especially potassium (200-900 mg/ 100 g), vitamin B3 (360-3300 µg/100 g) and vitamin C (10-30 mg/100 g). Heat treatment deprives potato tuber 10-40% of the vitamin C contained in it. However, still taking into account the amount of potatoes consumed by Poles, the potatoes remain one of the most valuable sources of this vitamin in the daily diet [4].

Potato is also a food product of low energy value which is popular among consumers particularly interested in a healthy lifestyle. The potato calorific value varies from about 50 kcal/100 g (with a starch content in the range of 10-12%) to about 80 kcal/100 g (with a starch content of up to 16%). The relatively low starch content in the potato tuber makes its average energy value (about 65 kcal/100 g) remains almost five times lower than in the case of wheat bread (275 kcal/ 100 g) and nine times lower than in the case of full chocolate (540 kcal/100 g), maintaining a calorific value comparable to full fat milk (62 kcal/100 g) [5].

Table 1. Average monthly consumption of selected food stuffs per capita
Tab. 1. Przeciętne miesięcznie spożycie niektórych artykułów żywnościowych w przeliczeniu na jednego mieszkańca

Specification	**2010**	**2016**
Bread and cereals [kg]	7,05	5,88
Meat [kg]	5,61	5,32
Fish and seafood [kg]	0,46	0,32
Milk [l]	3,53	3,08
Yoghurt [kg]	0,54	0,53
Cheese and curds [kg]	0,95	0,85
Cream [kg]	0,38	0,36
Eggs [szt.]	12,91	11,64
Oils and fats [kg]	1,36	1,13
Fruits [kg]	3,46	3,66
Vegetables [kg]	10,06	8,59
of which potatoes [kg]	**4,88**	**3,48**
Sugar, jam, honey, chocolate and confectionery [kg]	1,77	1,78
Coffee [kg]	0,19	0,18
Tea [kg]	0,07	0,05
Mineral or spring waters [l]	3,86	4,91
Fruit and vegetable juices [l]	1,06	0,97

Source: own study based on CSO data
Źródło: opracowanie własne na podstawie danych GUS

The domestic crop of consumer potato is usually stored in traditional (earth) and technical (foil) mounds, storerooms (farm and goods) and basements. In order to maintain the required quality of harvested crop, it is necessary to ensure optimal climatic and humidity conditions. Consumer potatoes should be stored at 4-6°C, maintaining air humidity in the range of 90-95% and adequate ventilation. Too high temperature fluctuations or excessive ventilation shouldn't be allowed, which may cause an increase in natural losses [6].

3. Materials and research methods

The aim of the project presented in this article was to develop an effective method of qualitative identification using neural modeling and image analysis of potato tubers belonging to one of three varieties: Denar, Gala and Vineta. These varieties, belonging to the culinary AB type, are popular both in Poland and in the Greater Poland Voivodeship, both among consumers and in the national seed industry. They are characterized by a dense structure, resistance to infection with yellow potato cyst nematodes (lat.: *Globodera rostochiensis*) and high taste.

The Denar variety is characterized by a very good storage value, suitable for cultivation in traditional systems and under covers. The early variety Gala also belongs to universal varieties. The Vineta variety, originating from Germany, is also

suitable for cultivation in a traditional system, and like the Gala, it is characterized by excellent storage (Table 2).

Table 2. Characteristics of selected edible potato varieties
Tab. 2. Charakterystyka wybranych odmian ziemniaka jadalnego

Tuber characteristics	Denar	Gala	Vineta
Shape	round-oval	round-oval	round-oval
Flesh color	light yellow	yellow	yellow
Skin color	yellow	yellow	yellow
Size	9	8	8
Taste	7,3	8	7
Storage durability	7	9	9
Culinary type	AB	AB	AB
Type of variety	very early	early	early

Source: own study, based on http://www.granumfn.pl/, access: 29.04.2018
Źródło: opracowanie własne na podstawie: http://www.granumfn.pl/, dostęp: 29.04.2018

To achieve the project's objective, a measurement and research stand was used at the Institute of Biosystems Engineering at the University of Life Sciences in Poznan. The stand consists of a shadowless chamber and apparatus for acquiring digital images. For each of the above edible potato varieties, about 4000 photographs were obtained, which were then used to create a graphic database, which was the basis for the training set. In order to classify, a set of twenty image descriptors, constituting input variables of the neural model, was adopted.

a) Geometric parameters of the model:
- height (MAX_WYSO): the largest distance between the extreme pixels of the image,
- width (MAX_SZER): the shortest distance between the extreme pixels of the image.

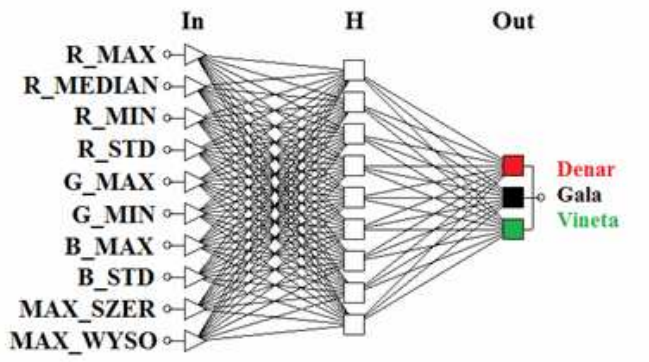
b) Shape factors:
- Feret coefficients (WSP_FER): the coefficient value is the quotient of the width and length of the object.

c) Parameters of the RGB color space model, describing the values of red, green and blue (with a value in the range of 0-255), and appropriate statistical values of channels of the color space model:
- red: color value (COLOR_R), maximum (R_MAX), minimum (R_MIN), mean (R_MEAN), median (R_MEDIAN) and standard deviation (R_STD),
- green: color value (COLOR_G), maximum (G_MAX), minimum (G_MIN), mean (G_MEAN), median (G_MEDIAN) and standard deviation (G_STD),
- blue: color value (COLOR_B), maximum (B_MAX), mean (B_MEAN), median (B_MEDIAN) and standard deviation (B_STD).

The training set created (as well as the validation and test sets) consists of 4776 (Denar), 3215 (Gala) and 4009 (Vineta) training cases respectively. For each of the training sets, the above input variables and one (three-way) output variable that classifies the given learning case to the appropriate variety were used.

In the process of searching for the appropriate topology of artificial neural networks, solving the issue of identification of edible potato varieties based on a previously performed digital image analysis using the “Statistica Neural Networks 4.0” software from StatSoft, a set of neural networks was generated, containing:
- three linear networks,
- two networks with radial basic functions RBF (Radial Basis Functions),
- eighteen MLP networks (Multilayer Perceptron).

These networks have been subject to testing in the application "Statistica Neural Networks 4.0". Network most effectively solving the problem of identification of the variety of edible potato was a multilayer perceptron MLP, with the structure 10: 10-9-3: 1. The resulting neural model has 10 neurons in the input layer, 9 neurons in the hidden layer, and 3 neurons in the output layer.



Source: own study / Źródło: opracowanie własne

Fig. 2. Scheme of the created neural model – MLP neural network
Rys. 2. Schemat wytworzonego modelu neuronowego – sieci neuronowej typu MLP

Among the values of twenty image descriptors, ten of the highest significance were selected - maximum, minimum, median and standard deviation of red, maximum and minimum of green, maximum and standard deviation of blue, as well as height and width - thus obtaining ten input variables. The three-way input variable classified the elements of the training set, giving them the values of Denar, Gala or Vineta respectively. The generated neural model was trained using the supervised methods: Delta-Bar-Delta, conjugate gradients method and the error backpropagation method, among which the most effective method was the BP (BackPropagation) method. The value of RMS (Root Mean Square) error using above training method was:

a) for the training set - 12.54%
b) for the validation set - 14.86%
c) for the test set - 13.75%.

The quality of the created neural model, which is the number of correct classifications in relation to the size of the training set, has reached a very high level:
- for the training file: 0.96753
- for the validation set: 0.95358
- for the test set: 0.96498.

Sensitivity analysis of the generated neural model allowed to determine the rank of input variables affecting the functioning of the artificial neural network. The error ratio in all cases had a value greater than 1, which indicates that all input variables affect the correct functioning of the created neural model. The standard deviation of the blue color was the least significant variable, the median of the red color was the most important one.

4. Summary

The implemented solution made it possible to obtain several neural models effectively solving the problem of qualitative identification of selected edible potato varieties. The created neural models confirm the high importance of quality features described by means of selected parameters of the potato tuber color and shape [10]. Analysis of the generated models of artificial neural networks indicates that the described classification problem most effectively solves a multilayer MLP perceptron having 10 neurons in the input layer, 9 neurons in the hidden layer and 3 neurons in the output layer. The effectiveness of the model is confirmed by the low RMS error value and a very large number of correct classifications.

The artificial neural network proposed above confirms that the use of neural modeling and image analysis methods is an innovative and effective tool for quality control of the obtained potato crops. The presented model can be the basis of many decision support systems, more and more commonly used in agricultural engineering.

5. References

[1] Boniecki P.: Elementy modelowania neuronowego w rolnictwie. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, 2008.

[2] Rozkrut D. (red.): Rocznik Statystyczny Rolnictwa 2017. Warszawa: Zakład Wydawnictw Statystycznych, 2016.

[3] Sęk T., Przybył J.: Technika i technologia produkcji ziemniaków. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, 2015.

[4] Lisińska G., Leszczyński W.: Potato science and technology. Elsevier Applied Science, London 1989.

[5] Kunachowicz H., Nadolna I., Iwanow K., Przygoda B.: Wartość odżywcza niektórych produktów spożywczych i wybranych potraw. Warszawa: Wydawnictwo PZWL, 2011.

[6] Sęk T., Przybył J.: Projektowanie inżynierskie procesów technologicznych. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, 2015.

[7] Koszela K., Weres J.: Neuronowa klasyfikacja obrazów suszu warzywnego. Inżynieria Rolnicza, 2009, 8 (117).

[8] Tadeusiewicz R.: Sieci neuronowe. Warszawa: Akad. Oficyna Wyd. RM, 1993.

[9] Orłowski M., Kołota E.: Uprawa warzyw. Szczecin: Wydawnictwo BRASIka, 1999.

[10] Boniecki, P., Nowakowski, K., Tomczak, R.: Neural networks type MLP in the process of identification chosen varieties of maize. In: Third International Conference on Digital Image Processing (ICDIP 2011), Proceedings of SPIE, 2011.