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DEVELOPMENT OF PROTOTYPE GRADING SYSTEM FOR REAL-TIME IDENTIFICATION OF FUSARIUM DAMAGED CORN SEEDS BY COLOR IMAGE ANALYSIS AND CLASSIFICATION

Annotation

This research was aimed to develop a prototype system for real-time detection of Fusarium damaged corn kernels. The system could continually present one by one positioned corn kernels to CCD camera, singularize each image from the background, and discharge seeds to assigned containers. The software was developed in the LabVIEW environment to provide graphical and user–friendly interface. The image analysis and classification procedures were performed using MATLAB connection with the main program for machine control. The results related to 1120 seeds from variety Kneja 436, show that the automated inspection system could correctly categorize over 95% of corn seeds based on comparison with human inspection.

Keywords: Corn seeds, Fusarium, Image Analysis, LabVIEW and Classification
Ключевые слова: зерна кукурузы, Fusarium, анализ изображения, LabVIEW, классификация
Кілт сөздер: жүгері дәндері, Fusarium, бейнені талдау, LabVIEW, топтастыру.

Introduction

The Fusarium head blight (FHB) is a serious fungal disease, which is very destructive and is one of the most important fungal diseases affecting corn in all cropping areas of the world [8]. Damage from head blight, also known as scab, involves shrunken and discoloured (pink or chalky white ‘‘tombstone’’) kernels, and causes reductions in yield and seed quality. Fusarium head blight also reduces test weight and lowers market grade. The infection is spread by wind, birds, but planting infected seed also spreads the pathogen. Increasing labor productivity in the preparation of corn seeds is an important task that requires the inculcating of new, more effective forms of work organization and application of industrial methods for quality control. Till now in our country the seeds are graded by hand and often the agro-technical requirements are not met fully. This led first to the great expense of labor and means of production unit that is in low labor productivity, poor production and lower yields.

A review of the trends in the field of agricultural and food technology shows general approach to implementation of high-speed automatic grading systems. Interest for the automatic grading and sorting by quality of grain products are the real time working sensors, so the inspection is carried out without damaging the products. Nowadays, the use of automated systems in a working industry is necessary. They have enormous potential, relatively low cost, easy control, high speed, high productivity and a wide field of application. Main activities that a standard automated system can easily do in the field of agriculture are: fault detection, classification of products by shape, size, color, inspection of varieties, sorting by quality, maturity, process automation for storage and processing of food.

Analysis of existing advanced automated grading systems proposed by several authors [1, 2, 3, 5, 9, 11, 12, 13] shows that the basic requirements that need to be covered are: providing regular submission of sites in the area of inspection; complete scan of objects, removing the unuseful signal, containing the necessary information upon which the chosen algorithm recognizes which of the given class belongs graded product, and then through the control pulses to the actuator directs it to the appropriate quality fraction.

The trend to fast and cheap multipurpose solutions (software or hardware) in image processing is especially important to the industrial environment, because there is an increasing demand for cost-effective and high quality products that can only be fulfilled only by very sensitive, automated quality monitoring. Moreover, the industry is a volatile and competitive environment thus industrial applications must be flexible enough to adjust to new production methods. These requirements call for multipurpose hardware and mainstream Operating Systems (OS), so that fast image processing can be achieved with moderate cost.

Aim of the present work is the development of prototype for on-line classification and grading of corn kernels in two categories - healthy and diseased with Fusarium Moniliforme. The structure, principle of operation and the algorithms for image analysis are briefly explained. The performance of the developed system and the accuracy of the classification procedure with test sample of kernels are tested.

Materials and methods

1 ***Corn samples***

The corn samples used in this study were collected in two following crop years. A total of 1120 corn samples, 700 sound kernels and 420 diseased with Fusarium, from variety "Kneja 436" were analyzed. Images of kernels are shown in Fig.1.

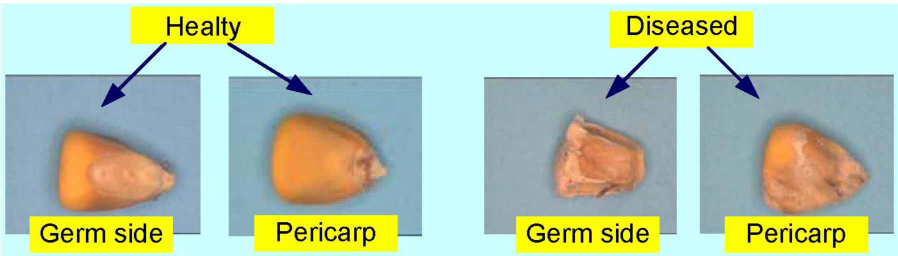


Figure 1 – Images of sound and Fusarium damaged corn seeds

2. Design and implementation of the system

The global structure of the system is shown on fig.2. There are specified three general levels – Hardware level, Software level and User Interface level.

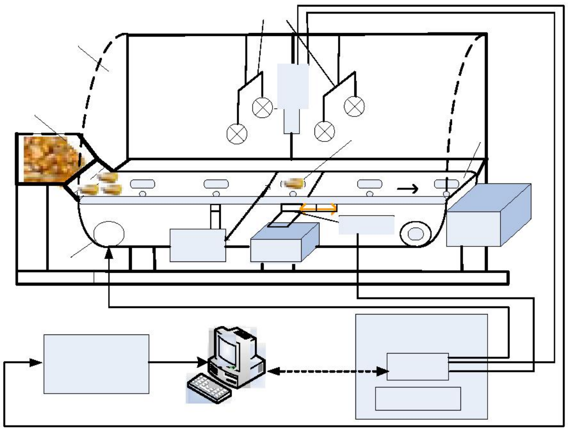


Figure 2 – Global structure of prototype system

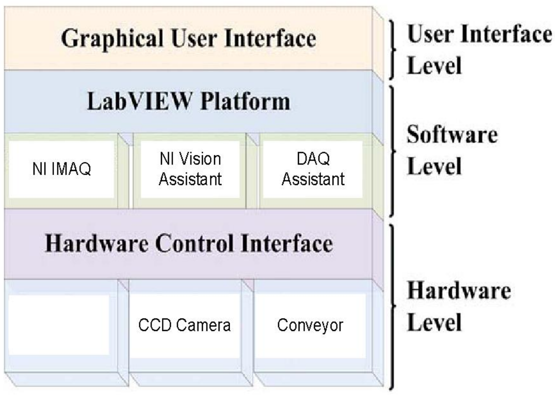


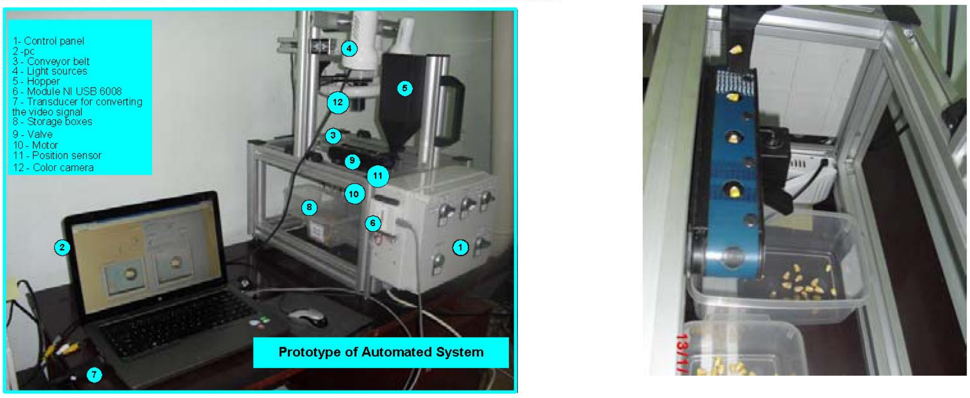
Figure 3. Design schema of the system

2.1. Hardware level

The system is consisting of aluminum profiles measuring 38 cm. – Width, 63 cm. - Length and 72 cm. - Height. The movement of the kernels is ensured by conveyor belt, which is driven by a DC motor. Conveyor is opaque with a dark blue color and width 3 cm. Along the belt off 3.5 cm apart are formed round holes with a diameter of 1.5 cm. The color of the belt is selected according to the fact that the blue color does not appear in either the colors inherent in corn kernels, or to typical color coating, which forms fungi from Fusarium

Moniliforme. This allows a clear separation of the object from the background color, which is important when analyzing only the pixels belonging to the object.

On fig.4. is shown the developed automated recognition system, which distinguishes between healthy and infected with Fusarium Moniliforme corn kernels.



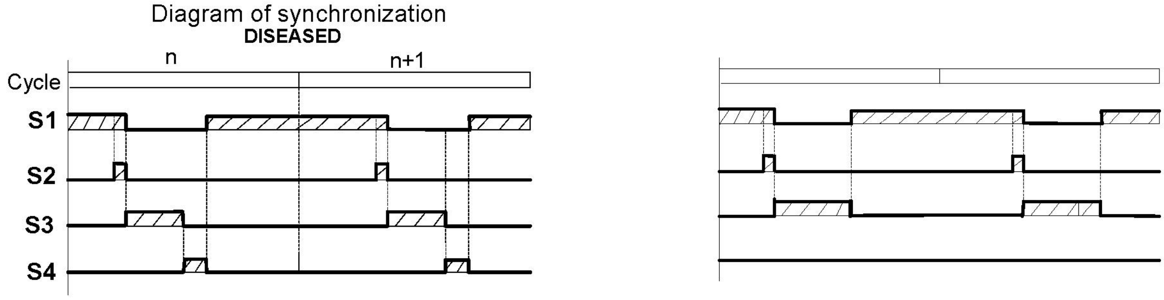
a) b)

Figure 4. Main parts of the developed prototype system for grading of Fusarium damaged corn seeds

The automated System (fig.4) consists of: 1- control panel, 2- personal computer, 3- conveyor belt (fig.4b.), 4 - light sources, 5- Hopper, 6 -Module NI USB-6008, 7 - transducer for converting the video signal, 8 - storage boxes, 9 – Valve, 10 - motor, 11 - position transmitter, 12 - color camera. On Fig. 3c. can be seen the movement of the kernels on the conveyor - every kernel stood in a specially created round hole in the belt and it is situated (stops) in the working area perpendicularly under the camera. Valve, which is activating in the presence of infected grain classification is under the hole in the work area and hence over storage box, which is carrying the infected kernels.

- Camera unit - Charge couple device (CCD) color camera (Sony VIDO CC422S) with a zoom lens of 5-50 mm focal length (F:1.6, Tokina, Japan). The camera is situated square to the work area and the distance between the camera and the object is 26 cm.
- converter device - connection between camera and PC is via device Synetec 4CH USB 2.0 DVR
- Lighting Unit – consists of two sources - Source 1: fluorescent ring body - Philips TL-E 22W/54-765 diameter of 30 cm perpendicular above the working scene around the camera lens in order to achieve uniform illumination of the object without the appearance of shadows. Source 2: LED bulbs
- converter module - device for communication between a PC and sorting system ADC NI USB 6008, production for National Instruments.
- position sensor - inductive sensor.
- Electric motor – AC motor.
- PC - The system is equipped with computer HP G62 (Intel Pentium 4, CPU: 6100, 2.0 GHz, RAM: 3 GB, OS: Windows 7 Ultimate).

The system control unit is mainly responsible for synchronizing camera triggers with the movement of the kernels upon the transporter and controlling the valve using decisions for the corn condition from the image processing and classification unit. The diagrams of synchronization for the possible conditions of seeds are shown in Figs.5.a,b.



a) b)

Figure 5 – Diagram of synchronization of the system actions in case of healthy or diseased seed

2.2. Software level

Powerful Graphical User Interface (GUI) environments running on PCs provide the core technologies necessary for building powerful, user-friendly machine vision environments at moderate cost. System development involves integration of software and hardware tools into a complete application. Today's machine vision systems are offering far easier integration of various components originating from various software and hardware vendors. Even conventional programming environments such as C and C++ allow for software components to be embedded into a single system. Image processing software has become user friendly and powerful utilizing software libraries implementing some of the most popular image processing and analysis algorithms. Most of these environments support both, visual programming in combination with flexible GUI interfaces and traditional programming. Both programming practices can be combined to facilitate application development. Visual programming can be employed to accelerate application's prototyping whereas the final application can be implemented and optimized using standard programming methods and languages.

The current trend in industrial vision is to use commercial products instead of customized [6]. This reduces the effort and risk in developing new products and allows for immediate exploitation of new hardware. When higher performance is needed, specialized DSP processors can be used. The selection of the appropriate software tools is of crucial importance. A software tool must have the following desirable features:

• Multi-processing level support: The type of processing in an industrial vision system varies from low level (e.g., filtering, thresholding), to medium level (e.g., segmentation, feature computation) and high level (e.g., object recognition, image classification etc.). An image software package must support all levels of functionality. Otherwise, different software tools must be adopted and integrated into the same system.

• Ease of manipulation: Graphical user interfaces, visual programming and code generation are typical features facilitating application development. Image functions must be categorized by type and scope so that even a non-expert may choose the appropriate function based mostly on what it does rather than on how it is done.

• Dynamic range and frame-rate support: software must support the processing of high dynamic range images (proposed by new types of sensors e.g., CMOS sensors, which offer faster image acquisition and high dynamic range - 16 bits per pixel instead of 8) at variable frame rates.

• Expandability: The software package must be able to accommodate new or better algorithms substituting old ones. In addition, the software package must easily adjustable to new requirements of the running application without major programming effort.

• Dedicated hardware support: The software package must be able to work in collaboration with different type of hardware.

The selection of programming language is based on large literature research where have been mentioned many programming languages used to develop this kind of software as C + + (Evans et al., 1998; Yoon et al., 2011), Microsoft Visual Basic (Kim et al., 2001) and LabVIEW (Lerner and Drake, 1999; Martin et al., 2006). The choice of programming platform depends on many factors such as programming skills, the available hardware drivers etc. From the mentioned languages the LabVIEW - Laboratory Virtual Instrument Engineering Workbench (National Instruments, Austin, TX, USA) has some advantages over the others in terms of scientific application purposes. One of the main advantages of LabVIEW is it's rich library for designing graphical user interfaces (GUI) and a variety of hardware drivers. For example, this system is most practical to use LabVIEW NI-IMAQdx toolset, which provides serial communication between the computer and the camera (via Camera Link interface). In addition, LabVIEW is a graphical programming language based on Virtual instruments (VIs), which represent virtual hardware equipment and measured data. Graphically oriented programming allows design your program by dragging and dropping the appropriate icon. The software is designed to obtain a reliable, simple and easy to use program for managing automated recognition system for classification of corn based on their color. The program is flexible and allows easily be modified so that it is not only used for receiving and processing digital image standard, but also in various other research areas, such as acquisition and processing of spectral and hyperspectral imaging in the presence of the equipment.

The control of sorting machine is based on three LabVIEW modules: NI IMAQ, Vision Assistant and DAQ Assistant. Module NI Vision Acquisition software is the basic element in the development of this type of applications and includes the necessary drivers, namely NI-IMAQ and NI-IMAQdx through which easily controls the camera. IMAQdx driver allows use with different types of cameras - IEEE 1394 (FireWire), GigE Vision (Ethernet), and USB.

The system control unit is mainly responsible for synchronizing camera triggers with the movement of the kernels upon the transporter, transferring images from camera to the computer, and controlling the valve using the decisions for the samples.

The color image analysis and classification are implemented trough Vision Assistant and Matlab Script.

2.3. Level User Interface

Figure 6 shows the front panel of the developed LabVIEW program for real – time image acquisition and system control. The left side of the VI shows the real-time field of view of the camera; the field 'Error Code', which indicates if there is an error obtained while executing program code; indications 'Working Conveyor' and 'Conveyor in position for processing'; Stop button. On the right there is the main menu for corn variety selection, by default this is variety Kneja 308. All of the available submenus allow performing the following actions:

- Selection of folder for storing the images from the available folders on your computer;
- Visualization image of the last classified corn seed;
- Visualization of the results of the procedure for searching correctly positioned object in front of the camera (ROI – Region of interest);
- LED indication for the presence of a properly positioned object in the ROI;
- LED indication of the classification procedure result - green indication for sound seed and red indication for damaged seed;
- Fields for automatically counting classified sound and damaged seeds with option for zeroing the fields before starting work.

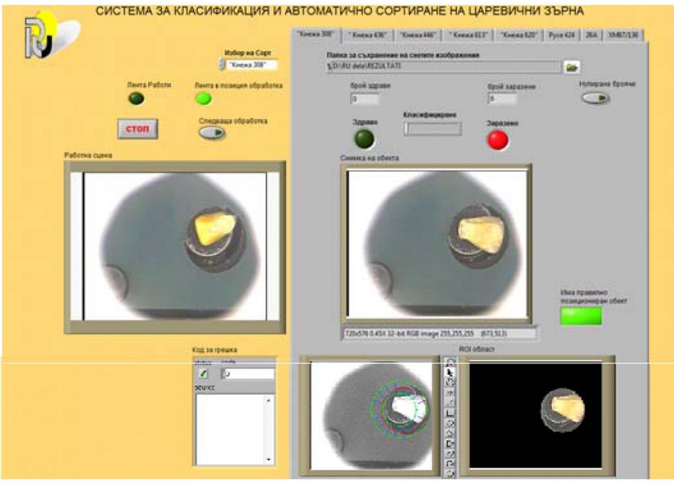
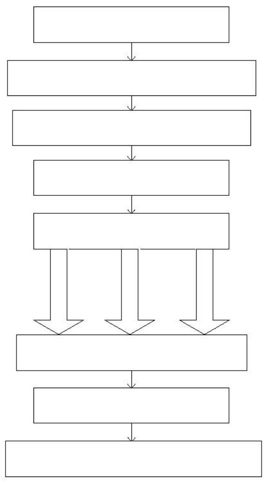


Figure 6. Front panel of the developed virtual instrument Figure



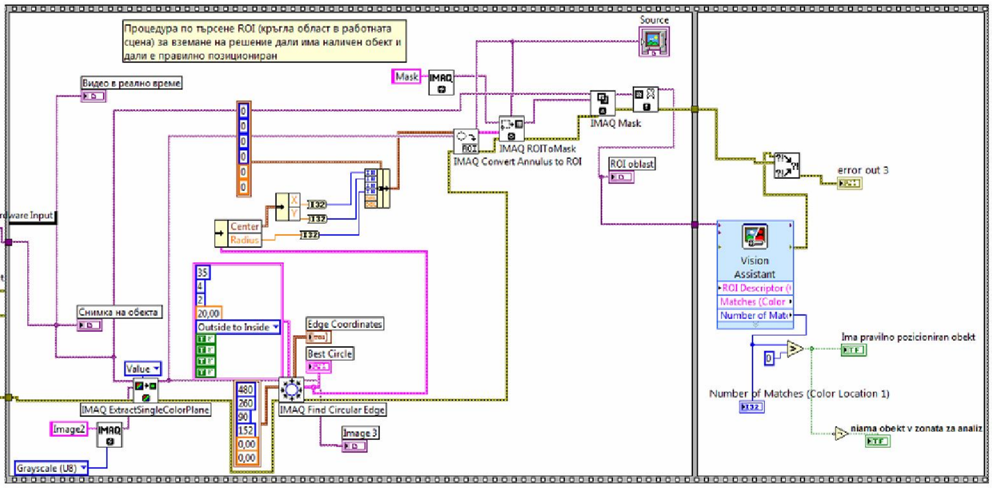
7. Flowchart of the image processing and classification algorithms for Fusarium damage detection

2.4. Software Level

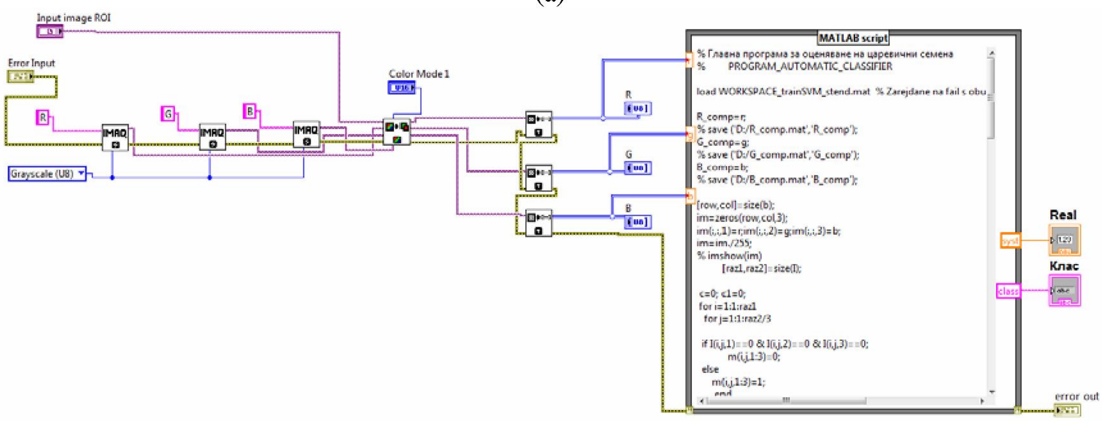
In the software design level of the developed automated system, LabVIEW 8.6. (National Instruments, Inc.) was adopted as software development and integration platform. NI IMAQ, NI Vision Assistant and NI DAQ packages were used to develop subroutines associated with image capturing, image processing and motion control, respectively.

The system control unit is mainly responsible for synchronizing camera triggers with the movement of the seed holders and controlling the valve using decisions for the corn condition from the image processing and classification unit.

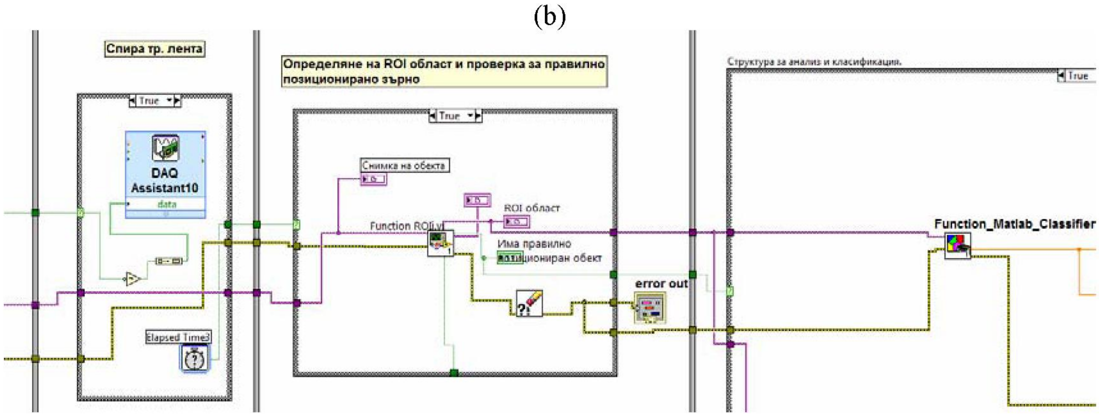
The first step is image registration. The template color searching function in LabVIEW Vision Development Module is used for searching the template color image of a seed in the ROI Region of interest to make decision whether there is properly positioned object. Illustration of the searching ROI subroutine is shown in Fig. 8 (a), in witch only partial portion of VI is illustrated for saving space. The identified ROI "A" and the cropped ROI area "B" for the current image can be seen on the Front panel of the VI (Fig.6.).


Source
Процедура по търсене ROI (кръгла област в работната сцена) за вземане на решение дали има наличен обект и дали е правилно позициониран
Видео в реално време
Mask
IMAQ Mask
IMAQ ROIToMask
IMAQ Convert Annulus to ROI
ROI oblast
error out 3
Camera Hardware Input
Center
Radius
Error Input
Снимка на обекта
Vision Assistant
ROI Descriptor
Matches (Color
Number of Mat
Ima pravilno pozicioniran obekt
Edge Coordinates
Best Circle
Outside to Inside
Value
Number of Matches (Color Location 1)
IMAQ ExtractSingleColorPlane
IMAQ Find Circular Edge
Image2
Image 3
niama obekt v zonata za analiz
Grayscale (U8)

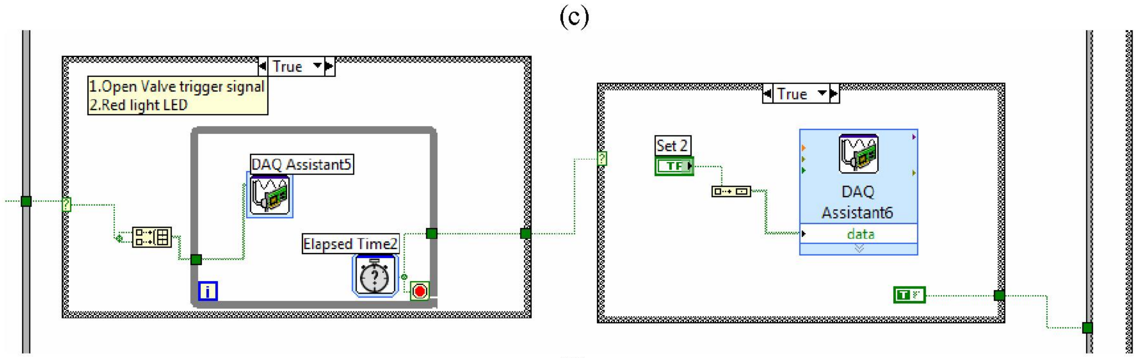
(a)


Input image ROI
Error Input
Color Mode 1
R
G
B
Grayscale (U8)
MATLAB script
% Главна програма за оценяване на царевични семена
% PROGRAM_AUTOMATIC_CLASSIFIER
load WORKSPACE_trainSVM_stend.mat % Zarejdane na fail s obu
R_comp=r;
% save ('D:/R_comp.mat','R_comp');
G_comp=g;
% save ('D:/G_comp.mat','G_comp');
B_comp=b;
% save ('D:/B_comp.mat','B_comp');
[row,col]=size(b);
im=zeros(row,col,3);
im(:,:,1)=r;im(:,:,2)=g;im(:,:,3)=b;
im=im./255;
% imshow(im)
[raz1,raz2]=size(I);
c=0; c1=0;
for i=1:1:raz1
for j=1:1:raz2/3
if I(i,j,1)==0 & I(i,j,2)==0 & I(i,j,3)==0;
m(i,j,1:3)=0;
else
m(i,j,1:3)=1;
end
Real
Клас
error out

(b)


Спира тр. лента
True
DAQ Assistant10
data
Elapsed Time
Определяне на ROI област и проверка за правилно позиционирано зърно
Снимка на обекта
ROI област
Function ROI.vi
Има правилно позициониран обект
error out
Структура за анализ и класификация.
Function_Matlab_Classifier

(c)


True
1.Open Valve trigger signal
2.Red light LED
DAQ Assistant5
Elapsed Time2
Set 2
DAQ Assistant6
data

(d)

Figure 8. Illustration for several subroutines developed by Vis on LabVIEW platform: (a) Searching ROI subroutine, (b) digital image processing subroutine, (c) and (d) hardware control subroutines

For the current image are formed three integer arrays with color data of each pixel corresponding to R, G and B components. These arrays are fed directly as inputs to the MATLAB Script (Fig.8.b.), since there is the algorithm for the classification of objects studied by analysis of the color components. The procedure for classification is using nine previoulsy extracted features, which resulted from Principal Component Analysis (PCA). The classification method, which has been tested is the Quadratic Bayes classifier in combination with Leave-one-out cross validation – LOO. The choice of the classifier is based on the literature preview [4, 10] and the fact, that this particular classifier gives optimal solution for classes with overlapping areas, in terms of the risk of misclassification. The implemented classification method is based on well-known formula for the full Bayesian probability for making a decision, taking into account a priori probabilities or densities of the probability distribution of belonging to the relevant class and conditional probabilities:

$$P(\omega_i | X) = \frac{P(X | \omega_i) P(\omega_i)}{P(X)}$$

where $P(\omega_i | X)$ is the probability of belonging to the ω_i class of image X. Discriminant analysis using Bayesian estimation is used to obtain the classification accuracy of the proposed automated system.

3.Results and discussion

To assess the quality of the classification used test samples in which the observations are selected at random. The classification results are given in Tables 2 and 3. Table 1 shows the confusion matrix for the classifier procedure.

Table 1 – Confusion Matrix for corn seed classification with four classes

Confusion Matrix			Classifier results			
		Number	Diseased, smooth	Diseased, germ	Sound, smooth	Sound, germ
Actual Class	Diseased, smooth	210	45.71	51.43	2.38	0.48
	Diseased, germ	210	13.33	85.24	0	1.43
	Sound, smooth	350	4.29	0.29	93.14	2.29
	Sound, germ	350	4.00	3.71	7.71	84.57

Table 2 – Classification results for corn seeds in four classes from variety Kneja 436

Actual Class	*Seed condition*	*Number*	*Misclassified*	**Accuracy(%)**
Sound	Sound – smooth side	350	25	93,14
	Sound – germ side	350	54	84,57
Diseased	Diseased – smooth side	210	114	45,71
	Diseased – germ side	210	31	85,24
Total		1120	224	77,17

Table 3 – Classification results for corn seeds in two classes from variety Kneja 436

Actual Class	*Number*	*Misclassified*	**Accuracy(%)**
Sound	700	43	93,86
Diseased	420	8	98,10
Total	1120	51	95,98

CONCLUSIONS

From the interpretation of the results in the given tables clearly emerges the conclusion that two by two classes respectively "diseased smooth" and "diseased germ" and "sound smooth" and "sound germ' differ by less likelihood. This reason and the fact that the leading question concerns the distinctness of the condition of the seeds without the necessity of determining the side of capture, leading to pooling of classes, respectively - Class "Sound" and Class "Diseased." Thus, the total accuracy of classification has grown from 77,17% to 95,98%. Overall performance of the developed system satisfies the requirements for quality control of corn, in terms of Fusarium Moniliforme detection. The time necessary for processing of one seed is of the order of 1 second and the accuracy of classification satisfies the statutory standards for Bulgaria.

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РАЗРАБОТКА ПРОТОТИПА СИСТЕМЫ ДЛЯ ИДЕНТИФИКАЦИИ В РЕАЛЬНОМ ВРЕМЕНИ "FUSARIUM" ПОВРЕЖДЕННЫХ СЕМЯН ЗЕРНА КУКУРУЗЫ ПУТЕМ АНАЛИЗА ЦВЕТНЫХ ИЗОБРАЖЕНИЙ И ИХ КЛАССИФИКАЦИЕЙ

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Резюме

Результаты исследований направлены на разработку прототипа системы для обнаружения Fusarium (фузариоз) поврежденных зерен кукурузы в режиме реального времени. Система может постоянно инспектировать, расположенные по одному кукурузные зерна CCD-камерой, выделять изображение зерна от фона, и разделять семена на две категории: «здоровые» и «зараженные». Программное обеспечение разработано в среде LabVIEW и предоставляет пользователю удобный интерфейс. Анализ изображений и процедура классификации проводился с использованием программы MATLAB связанной с основной программой машинного управления. Результаты экспериментальных исследований 1120 зерен кукурузы сорта «Кнежа 436» показали, что автоматизированная система контроля может правильно классифицировать более 95% семян кукурузы по сравнению с инспекцией человеком.

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Түрлі-түсті бейнені талдау жолымен жүгері дәндерінің «Fusarium» зақымдалған тұқымын шынайы уақытта идентификациялауға арналған жүйенің прототипін және оларды топтастыруды әзірлеу

Резюме

Зерттеулер нәтижесі шынайы уақыт режимінде Fusarium (фузариоз) зақымдалған жүгері дәндерін табуға арналған жүйенің прототипін әзірлеуге бағытталған. Жүйе бір-бірден қойылған жүгері дәндерін CCD-камерасы арқылы әрдайым тексеріп отырады, дәннің бейнесін реңнен ажыратады және тұқымды екі категорияға бөледі: «таза» және «зақымдалған». Бағдарламамен қамтамасыз ету LabVIEW ортасында әзірленген және қолданушыға ыңғайлы интерфейс ұсынады. Бейнені талдау және топтастырудың рәсімі негізгі бағдарламалы машиналық басқарумен байланысқан MATLAB бағдарламасын қолдану арқылы жүргізілді. «Кнежа 436» сұрыпты жүгерінің 1120 дәніне жасалған эксперименталды зерттеулердің нәтижелері бақылаудың автоматтандырылған жүйесі адам тексеруімен салыстырғанда жүгері дәндерін 95%-дан аса топтастыруға мүмкіншілігі бар екенін көрсетті.

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