

## Smart sorting method of grains using a colour sensor

**Ifeoluwa E. Elemure**

Dept. of Mechanical & Design Engg.  
University of Portsmouth, UK

**Abiodun E. Amoran**

Dept. of Electrical & Electronic Engg.  
Federal University Ado-Ekiti, Nigeria

**James O. Akinyoola**

Dept. of Mechanical & Mechatronics Engg.  
Afe Babalola University, Ado-Ekiti, Nigeria

**Edwin A. Oshin**

Dept. of Biomedical Engg.  
Old Dominion University, USA

**Aderinsola M. Olawumi**

Dept. of Physics Electronics  
Federal University of Tech., Akure, Nigeria

**Temitope V. Adebambo**

Dept. of Physics  
Federal University of Agriculture, Makurdi

**Abstract-**This article presents a model construction of a computer system that recognises and sorts cowpea grains from unwanted particles. A high-speed, low-cost and image-based sorting device was used in detecting and separating cowpea grains from other particles having slight colour differences or defects. The device is a linear combination of the colour image sensor with a Field-Programmable Information Integration Technology of Gate Array (FPGA). The elaborated digital system applies filters to the images through the colour sensor TCS3200, which performs the detection of the grains. A neural network system was used for the automatic recognition of the Cowpea grains for an industrial information application. This was achieved through the implementation of software EasyEDA with Arduino programming process, which allows moving from a qualitative to a quantitative paradigm with the use of different mathematical tools and artificial intelligence. This enhances the speedy process of recognition and sorting of cowpea grains. A success rate of  $(90.67 \pm 3.13)\%$  was achieved in colour recognition, which is much higher than previously developed image inspection systems and highly promising for use in an automatic sorting system in the manufacturing industry.

**Keywords-**Colour sensor TCS3200; cowpea sorting; Neural Networks; Digital Image Processing; Field- Programmable Gate Array;

### I. INTRODUCTION

As of 2016, approximately 69% of the sub-Saharan African population had agriculture as the primary occupation which served as their source of living and food security. Hence, growth in agriculture production and productivity are essential for eradicating poverty and malnutrition in Africa. However, sub-Saharan Africans produce the lowest agricultural product per capita in the world [1]. One of the primary causes of this low production is the poor post-harvest processing of farm produce [2]. Due to society's growing interest in promoting environmental conservation, protecting natural resources and at the same time promoting their sustainable use in harmony with nature, innovative research on an interdisciplinary nature is imperative.

This prompted us to propose this paper to detect and recognise cowpea grains, which is one of the essential protein foods in Africa. This was achieved through pre and post-processing of digital images in the colour sorting method. The aim is to create a computerized system for automatic sorting of grains [3]. This made it necessary to construct a system that can measure or identify the characteristics of the family or species needed and displace others in order to establish characteristic differentiating patterns between them. Being an inter disciplinary project it yields a series of

benefits for the different parties. In the first instance, the need for a database of digital images of cowpea grains and a digitization system supports some areas of research such as beekeeping, archaeology and medical sciences [4]. Also, this digital collection of images is designed to consider the most critical types of cowpea from different regions of Costa Rica, which helps promote networks of knowledge and collaborative projects. This also promotes the recognition of the real importance of bees in pollination in tropical ecosystems in general as well as in crops with commercial importance.

It also to encourage the production of food derived from honey. Finally, the identification of timely cowpea grains enables the production of better honey and their derivatives, promote an economic projection for beekeepers and provides a certification that would provide the possibility of competing with international markets [5-6]. The research aims to model a system that automatically classifies cowpea grains using taxonomic criteria associated with the palynology of tropical honey plants and the application of digital image processing techniques for their detection. This article presents a description of the problem to be solved, the current state of the research and the applied methodology and the results that have been obtained in the first test phases. Commercial colour sorters can distinguish red and white

wheat with approximately 80% accuracy after several passes through the sorter [4-5] which may not always be accurate enough for some breeding lines with small amounts of white wheat. Additionally, the cost of these sorters is high, and they are designed to handle larger volumes rather than the smaller samples of 1 kg. However, in practice, it is a slow process, and its classification is subject to the determination of the characteristics of the grains observed in the microscope. This was possible as experienced specialists in cowpea morphology were involved. [5-6] Recently, investigations on system detection and classification of other grains based on the forms and textures were carried out. [7-9] proposed a cowpea grain sorting system based on the combination of shape and luminosity parameters.

The developed system consisted of the detection and recognition of the cowpea grain, extraction of characteristics and classification. These authors used descriptions of geometric characteristics, statistical moments, second-order statistical Fourier descriptors and luminosity characteristics. From this state, to respond to the need presented, this new research proposal was implemented. It consisted of designing and implementing a new version of a system of digital taxonomic detection and sorting of cowpea grains using pre and post techniques of the Processing of Digital Images.

This research aims to directly connect a low-cost colour processing sensor TCS3200 with a low-cost microcontroller board and to program the FPGA to have simple features capable of classifying objects in the image. The test objects were white cowpeas commonly available in Africa, with and without damage. The research was developed in three main phases. The first phase is obtaining the database of the digital images, which served as support for the entire protocol of experimentation. The second was the preprocessing of digital images, which was used to extract the images of each species of cowpea grains, giving it the enhancement of its characteristics and elimination of noise. Finally, the third phase is that of parameterization that was used to obtain an automatic classification system.

## II. MATERIALS AND METHODS

As it can be seen, in the TCS3200, the light-to-frequency converter reads an array of 8x8 photodiodes, 16 photodiodes have blue filters, 16 have green filters, 16 have red filters, and 16 are transparent without any filters. Likewise, a smaller version of the chip which was used can be seen, the TCS3210, whose matrix of photodiodes is 4x6, having six photodiodes for each type, instead of 16 as in the case of the previous. All photodiodes of the same filter type are connected in parallel. The configuration of the S2 and S3 pins will always configure the photodiodes to be active. To begin

working with the integrated module, we will need to configure several pins for the inputs and outputs, a timer in capture mode and an interruption to capture and measure the pulse width which is subsequently translated to the frequency and finally to colour. First, we create a function to configure the output pins that will be used to configure the sensors S0, S1, S2 and S3. These pins will be configured as outputs and will be connected to port B, as indicated in the tables in Fig. 1.

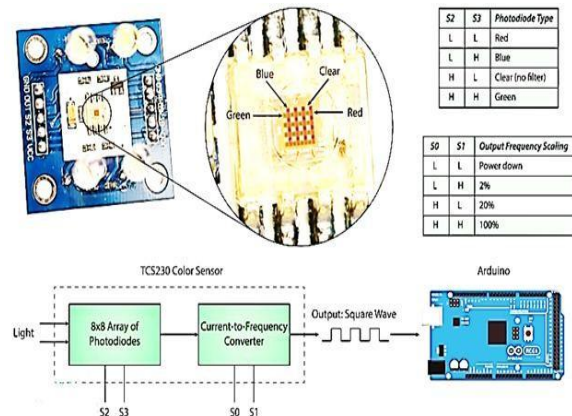


Fig.1 Configuration of the output of colour sensor TCS3200.

### 1. Modelling the database of digital images

The project began with the construction of the database of digital images from the CINAT collection of cowpea grains. For this phase, a test system was performed with a sample of 11 types of grains. Each type of grain has approximately 15 captured through a camera in a light microscope with a mechanical adapter. Although different colours have different sensitivity, for regular use which makes much difference. The UNO here sends signals to the module to detect colours, and the data received by the module are shown in the 16\*2 LCD connected to it. The UNO detects three colour intensities separately and shows them on the LCD.

The Uno can detect the signal pulse duration from which we can get the frequency of the square wave transmitted by the module. With the frequency at hand, we can match it with the colour on the sensor. An image capture protocol was used to construct baseline for each species analysed. In the first instance, the microscope was used with a lens of 100x increase and immersion oil for the recording of each photograph with controlled luminosity. Then individual transect photographs were taken along the entire surface of the sheet. In this way, the capture of the digital images under the same experimental conditions was assured according to the connection in Fig 2.

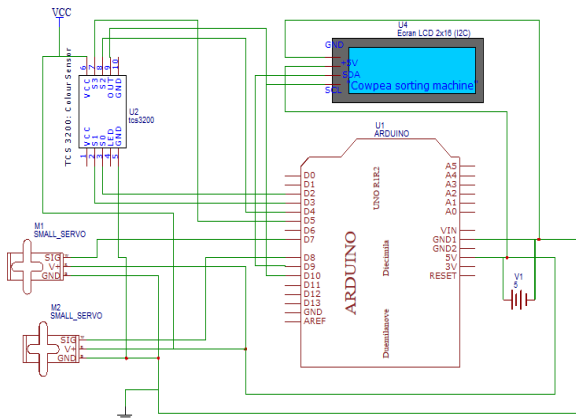


Fig. 2 Complete circuit diagram of the sorting machine

## 2. Pre-processing of digital images.

Once the images were captured, an automatic detector was run to evaluate only the cowpea grain information. As a first step, the contrast of the images was increased in order to increase the definition of the contours. Then we applied the particular stretching method explained in details in the research carried out by [10-11] where the main idea of the method consists of enhancing the equalization variance. The main operational design of cowpea sorting machine is shown in Fig. 3.

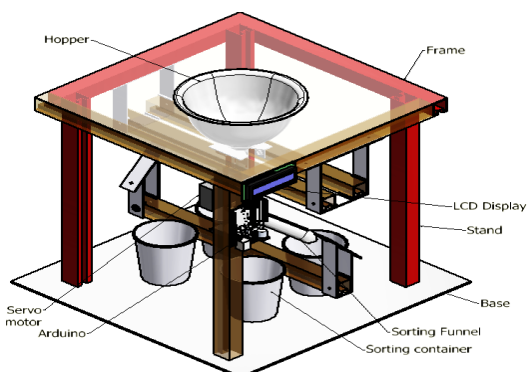


Fig. 3 Operational cowpea sorting machine.

The parameters selected in this work have been the area, the convex area and the perimeter. This is because they provide a considerable amount of basic information on the shape of the cowpea grains. The area is calculated as the number of pixels in the region under consideration. The convex area is calculated as the number of pixels in the binary image that specifies the convex envelope. The perimeter is calculated as the distance between each pair of adjacent pixels of the contour of the cowpea grain. Fourier descriptors represent the shape of the cowpea grain in the frequency domain [11-13]. A complex number can represent each point of the contour of the cowpea grain. In order to eliminate the effect of displacement, the centroid of the shape of the cowpea

grain is introduced in the representation of the contour in its complex equivalent. The contour has been sampled every 2 degrees using the Cartesian coordinate transformation to polar coordinates. Fourier descriptors were defined as the power spectrum of the discrete Fourier Transformations. A sample of different cowpea for sorting in this research is shown in fig.4.



Fig. 4. A mixture of different cowpea grain with other particles.

The marked reduction was performed using the colour sensing technique. Since there is a high correlation between input variables, it is possible to use the method of colour sensors to carry out this reduction [14]. In order to study the relationships between correlated variables which measure standard information, the original set of variables can be transformed into another set of new variables. These are correlated with each other and do not have repetition or redundancy in the information about the asset of principal components. The new flexible is linear groupings of the previous ones and are constructed according to the order of importance in terms of the total variability they collect from the sample. Preferably, we declare and assign values to two variables  $m, n$  where The conditions  $m, n$  represent linear combinations of the original variable  $p$  and they are correlated so the most of the information on the variability of the data is collected. This technique constructs a linear transformation that chooses a new coordinate system for the original set of data.

## 3. Automatic sorting

The different electronic component was used such as servo motor, resistors, Arduino UNO microcontroller, LCD screen and the colour sensor. The identification methodology used consisted of supervised classification. Therefore, the system has two modes training and testing. Artificial neural networks have been used in several works with good results [5-8, 15]. In some of these studies, Multi-Layer Perceptron neural networks have been used with the Multilayer Perceptron of back-propagation (MLP-BP) algorithm. The electrical

connection of the sensor and FPGA boards in feed-forward assembly and wiring system of the device to the servo motor is shown in Fig. 5. The activation function used in the neurons was a tangential hyperbolic sigmoid type. The neurons have the same number in the input layer was the same as the number of features selected. According to our experiments, the best number of neurons in the hidden layer ranged from 20 neurons to 80 neurons. It was determined that the appropriate number was 50 neurons. The number of neurons in the output layer was 11, that is, the number of classes. Five thousand iterations were made in the training phase.

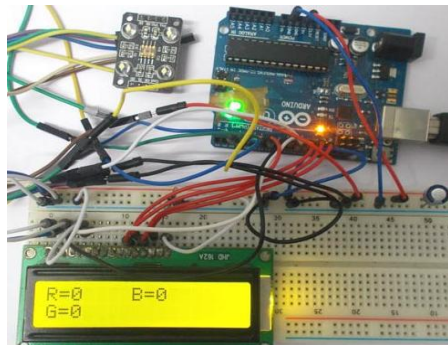


Fig. 5. Image sensor and FPGA boards connected in feed-forward assembly and wiring system of the device.

Since the initialisation weight of the neurons is random, 30 neural networks were used to affect the classification decision. Two methods were applied: top-rated class (CMV) and fusion of results by addition (AS). The first selects the most repeated results of the 30 neurons. These results are calculated in each neural network as the index containing the maximum value of the results, which corresponds to the sorting in the outputs of the 30 neural networks added before selecting the maximum value.

### III. RESULTS

In the preprocessing stage of the images, clusters of cowpea grains and out of focus images were presented. To eliminate this problem, semi-automatic capture algorithm was developed, to guarantee greater precision in the phase of parameter station and extraction of individual characteristics of the analyses species. As a result of this process, it was possible to extract the standardized and purified images that appear as images of the cowpea grains of the species extracted in the preprocessing phase.

The cowpea separated from different cowpeas are shown in Fig. 6. Once the preprocessing stage of the images was completed, the experiment continued with the use of the automatic classifier explained in the previous section. At this stage, we worked with two groups of samples: one for training and the other for control.



Fig. 6 Images obtained after the application of filters for the extraction of different grains of cowpea

The training group allowed us to generate results that were tested and verified with the control group. This process served as feedback and improved the sorting system. Also, the results were fused using the colour sensor TCS3200 technique. Finally, a check was made by experts on the information obtained and the success achieved was determined as the average of the fusion of the results. A value of 90.67% success was ascertained. The results obtained during this procedure were from the merging of parameters as input to the microcontroller via colour sensor TCS3200.

The current method for the classification of cowpea grains is a qualitative process which entails observing and differentiating cowpea grain characteristics. At this stage, the images of the eight species of cowpea grains used in the experiment were successfully debugged and extracted. Also, it was observed that the stretching procedure was effective in achieving the enhancement and sharpness of the images through the application of the equalization of the variance. These results agree with those of [17-18]. The success in the pre-processing of the analyses samples method continues by applying filters for the extraction of purified images, as shown in the Fig2.

Also, we verified that the combination of geometric characteristics and the Fourier descriptors are an excellent set of parameters for the classification of cowpea grains. This is because the geometric characteristics provide the general and basic information of the cowpea grains; while the Fourier descriptors allow more details according to the frequency studied. The lowest frequency descriptors contain information about the general characteristics of the form; the high-frequency descriptors contain information on the finer details. Since a subset of the generated descriptors is sufficient to describe the characteristics of the form, the Discrete Cosine Transformation (TDC) has been used to extract the most significant components. According to

[12-15], for the extraction of the contour of the cowpea grain, three variables were implemented, using Edge, Snake and Convex-Hull algorithms. Later, for the extraction of the characteristics of shape and texture, the authors worked with invariant parameters associated with morphology and ornamentation as well as with statistical moments that gave information about the contour and texture in grayscale. These variables were also successfully implemented in our study.

Fourier descriptors, first and second order statistics and texture characteristics were also used. Also, the experimental results, shown in table 2, indicate that the use of TCS320 as a sorting device in a combination of both sets of characteristics significantly improves the performance of the microcontroller [16-18]. This is consistent with the fact that the sensor TCS3200 transformation projects the data onto the dimensions containing more information, therefore, maximizing the variance.

Finally, with the fusion of the results of the parameters transformed with sensor TCS3200 and parameters without transformation using the AS technique, a success rate of 90.67% was obtained. The success achieved is like the 89% success rate, which was novel to other works. These authors used taxonomic categories based on classifiers of the minimum distance for the classification of cowpea grains. Also, an integrated pattern for classification with neuronal networks of multilayer and perception agrees with our work. Alternatively, and as a final discriminate, the above-cited authors used vector support tools.

#### IV. CONCLUSION

A novel method for colour sorting of cowpea grain was proposed in this research. The colour sorter system was designed using Arduino UO processor and image processing of TCS3200 for capturing and detection. This was for synchronizing its operations. The programming was done on Arduino software. The calibration of a machine was done with samples of different cowpea grains. This algorithm can be easily adapted for grading or sorting many other agricultural products. The colour sorting machine is not only used for better quality; it also saves energy as it uses an electronics component of 12volt rather than heavy motors. It is essential to mention that in our study, the number of species classified was more significant than that realized in previous works. For example, in the work of [18-22], the classification was limited to a sample of grains and not cowpea. The classification was obtained using a colour sensor to analyze the different cowpea species, especially after the parameter inaction with sensor TCS3200 values. The fusion of the results of the parameters transformed with sensor TCS3200 and parameters without transformation

using the AS technique yielded a success rate of 90.67%. It is concluded that the creation of a computer system for the automatic detection and sorting of cowpea grains is realizable and will be an essential tool to aid the food manufacturing industry.

#### REFERENCE

- [1]. Adebayo B. Abbas, Gabriel Ndunguru, Peter Mamiro, 211 Bamidele Alenkhe, Nicholas Mlingi, Mateete Bekunda. Post-harvest of semi-arid savannah area of Tanzania. Journal of Stored Products Research 57 (2014) 49-57.
- [2]. World Bank, FAO, NRI, 2011. Missing Food: the Case of Post-harvest Grain Losses in Sub-Saharan Africa. In: Economic Sector Work Report No. 60371-AFR. World Bank, Washington, DC.
- [3]. BI Oladapo, VA Balogun, AOM Adeoye, CO Ijagbemi, AS Oluwole, ..Model design and simulation of automatic sorting machine using proximity sensor, Engineering science and technology, an international journal 19 (3), 1452-1456.
- [4]. FARA, 2006. Framework for African Agricultural Productivity/Cadre pour la productivite Agricole en Afrique. Forum for in Africa, Accra, Ghana.
- [5]. Delwiche, S.R., T.C. Pearson, and D.L. Brabec. 2005. High-speed optical sorting of soft wheat for reduction of deoxynivalenol. Plant Disease 89(11):1214-1219.
- [6]. Adeyinka O. M. Adeoye, Bankole I. Oladapo, Adefemi A. Adekunle, Ayamolowo J. Olademeji, Joseph F. Kayode. Design, simulation and implementation of a PID vector control for EHVPMSC for an automobile with hybrid technology, Journal of Materials Research and Technology, Volume 8, Issue 1, January-March 2019, Pages 54-62.
- [7]. Pearson, T.C., D.L. Brabec, and S. Haley. 2008. Colour image base sorter for separating red and white wheat. Sensing Food Quality and Safety 2(4):280-288.
- [8]. Michael E. Kautzman, Mark L. Wickstrom, Tom A. Scott. The use of near-infrared transmittance kernel sorting technology to salvage high-quality grain from grain downgraded due to Fusarium damage. Animal Nutrition 1 (2015) 41-46.
- [9]. Vincent A. Balogun, Bankole I. Oladapo, Adeyinka O. M. Adeoye, Joseph F. Kayode, Samuel O. Afolabi, Hysteresis analysis of Thornton (IP6, IP12E and TH5V) magnetic materials using Arduino microcontroller. Journal of Materials Research and Technology, Volume 7, Issue 4, October-December 2018, Pages 443-449
- [10]. Inamdar, A. A. and Suresh, D. S. Application of colour sorter in wheat milling. International Journal 21(6): 2083-2089(2014).
- [11]. Francis T. omigbodun, bankolei. oladapo, oluwole k. bowoto, funso p. adeyekun, experimental model

- design and simulation of air conditioning system for energy management, international research journal of engineering and technology 6 (6), 811-816.
- [12]. AlanderJT,BochkoV,MartinkauppiB,SaranwongS, MantereT. A review of optical methods for food quality and safety. Inter J Spect 2013:1e36. Article ID341402.
- [13]. Bankole I. Oladapo, V.A. Balogun, A.O.M. Adeoye, C.O. Ijagbemi, Afolabi S. Oluwole, I.A. Daniyan, A. EsosoAghor, Asanta P. Simeon. Model design and simulation of an automatic sorting machine using the proximity sensor. Jestech 19 (2016) 1452–1456
- [14]. Pearson, T. C., 2009. Hardware-based image processing for high-speed inspection of grains. Computers and Electronics in Agric. 69(1): 12-18.
- [15]. Francis T. Omigbodun, Bankole I. Oladapo, Oluwole K. Bowoto, Funso P. Adeyekun, Modelling detection of magnetic hysteresis properties with a microcontroller. International Journal of Engineering Trends and Technology (IJETT) 67 (6), 5-12.
- [16]. Tom Pearson. Hardware-based image processing for high-speed inspection of grains, Computers and Electronics in Agriculture 69 (2009) 12–18.
- [17]. Bowoto, O.K.; Oladapo, B.I.; Nimako, P.A.; Omigbodun, F.T.; Emenuvwe, O.A. Arduino Fault Tolerant System, Internet of Things (IoT). Preprints 2019, 2019060034 (doi: 10.20944/preprints201906.0034.v1)
- [18]. Kumar, P.A., Bal, S., 2007. Automatic unhulled rice grain cracks detection by X-rayimaging. Transactions ofthe ASABE 50 (5), 1907–1911.
- [19]. Sujata R. Choudhari, D. V. Padole.Design of Color Sorter System by Using Arm Processor. International Journal of Computing and Technology, Volume 1, Issue 3, April 2014, 51-54.
- [20]. Vincent A Balogun, Omonigho B Otanocha, Bankole I Oladapo, Development of smart linear velocity measuring device by embedding sensors with the Arduino microcontroller, Proceedings of the 1st International Conference on Internet of Things and Machine Learning, Article No. 64, 2017.
- [21]. Juan Yan, Huibin Yang. Research on Workpiece Sorting SystemBased on Machine Vision Mechanism. Intelligent Control and Automation, 2015, 6, 1-9.
- [22]. Ou, X.Y., Hou, X.Z. Zheng, K.(2012). Machine Vision Based Automatic Teaching System of Six DOF 251 Robot. Manufacturing Automation, 34, 1-4.