ISO/IEC 25010 based evaluation of rice seed analyzer: A machine vision application using image processing technique

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ABSTRACT

The traditional approach for quality assessment of rice is done by a human inspector manually which leads to inconsistencies and uncertainties in the assessment due to human error. To address this problem, researchers develop rice classification systems applying different methods. The development of these kinds of applications will contribute to the larger objective of maximizing the production of global food. This study introduced a new method of rice seed classification that applies hashing techniques pre-processing of image prediction and its precision rate is 93.06 percent, with a speed of 8.31 seconds per image. The developed application in this study was evaluated using ISO/IEC 25010 with total mean scores of 4.31 for functional suitability, 4.31 for performance efficiency, 4.58 for compatibility, 4.31 for usability, 4.58 for reliability, 4.51 for security, 4.28 for maintainability, and 4.42 for portability.

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1. INTRODUCTION

Rice is the most essential agricultural plant in the Philippines and various other places in Asia. To obtain high-yield rice crops, it is necessary to foresee all the stages where the advancement of knowledge and technology [1] in quality control, coupled with consumers' expectations for high-quality food products for increased and improved production and quality monitoring. Generally, quality is defined as the sum of all features in a product, making it acceptable to consumers. The foundation of quality monitoring is often subjective with characteristics such as appearance, texture, smell, and taste. However, the working parts of agricultural machinery often damage cereal grains. The glaring difference between rice and other cereal crops is the economic and qualitative aspects of its production where the rice kernels are preferably obtained with less fissure and breakage when consumed. The economic value of the dried product strongly depends on the proportion of unbroken kernels. Broken kernels are typically worth approximately 50% or less than the value of undamaged rice [2]. This issue gives rise to the importance of rice quality monitoring compared to other cereal crops. Generally, in rice mills, due to the unavailability of a high-end measurement technique, the quality of the product is manually controlled and sorted. Moreover, a conventional method of grain quality evaluation and visual inspection, a manual method, is challenging even for trained personnel in terms of rapidity, reliability, and accuracy.

Recently, automatic inspection systems, based on computer vision technology [3] had been studied for the sensory analysis of agricultural and especially food products. Computer vision systems had been demonstrated to be useful for quality monitoring [4] and measurement of different agricultural and food products. Computer vision technology utilization in food production has long been recognized in the market. Recent progress in hardware and software has aided its growth by offering low-cost-effective solutions, steadiness, superior speed, and accuracy, resulting in increased efforts in the enhancement of computer vision systems in the rice industry. The exterior quality characteristics of food grains may undoubtedly be quickly and accurately determined using machine vision technologies. It is a challenge to connect these systems with those that can describe internal grain quality features, though. Machine vision systems can offer practical answers for various grain quality evaluations thanks to the advent of technology, as well as to the continuously expanding application needs and research advancements.

Machine vision systems have the capacity to take the role of manual techniques of inspection, which have become widely accepted in industries as a tool for assessing the quality of many agricultural goods. Several techniques and algorithms were already used to interpret and understand the information contained in a digital image of rice seeds. Some of the most notable techniques and algorithms include the threshold technique using the nil algorithm [5], maximum variance method using multi-class support vector machine (SVM) [6], image segmentation using the levenberg marquardt algorithm [7], image processing using minimum distance classifier [8], and k-nearest neighbor classifier and internet of things (IoT) using wireless sensor networks and microcontroller [9]. While these current methods of rice classification serve the needs of today, more and more methods are emerging to aid and promote the classification of rice. These methods would both lead to the larger objective of maximizing the production of global food [10].

This study presents an image processing technique using a hashing algorithm for rice seed classification. This method is extremely fast while being quite accurate compared to the other methods. Furthermore, this study developed a web application that provides rice farmers and traders a precise identification and classification of rice seed varieties. To evaluate the effectiveness of the application, a modified ISO/IEC 25010 software quality standards evaluation tool was used. ISO/IEC 25010 is a model of quality in use consisting of five characteristics (some of which are further subdivided into sub-characteristics) that contribute to the interaction outcome when a product is used in a specific sense of use [11]. This model of the system refers to the entire human-machine system, including both the computer systems in use and the software products in use.

2. METHOD

This study utilized the image processing technique based on the support vector machine model which is suited for the hashing algorithm and is capable of training data sets treated as a binarization set. This is like any supervised learning model with associated learning algorithms that analyze data used for classification and comparing image analysis. During the training, the model is taught to recognize images in various specific colors and whether the pattern received is accepted for hashing analysis and evaluation. Hashing is a popular [12] image retrieval technique. The supervised hashing method used in this data aim to improve hashing quality [13] by incorporating semantic labels into the learning process.

2.1. System development

The researcher developed a web-based application that aimed to provide a solution to the identified limitations as well as desired functionalities based on standards. Software development tools and machine learning models to generate output based on the image processing technique. The block diagram shown in Figure 1 represents the steps done to get the desired output from the collected images.

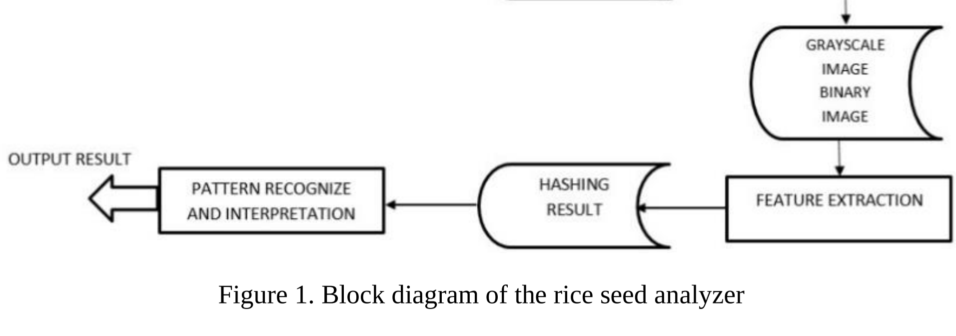


Figure 1. Block diagram of the rice seed analyzer

In this study, the rice seeds image was taken in a bird-eyes-view angle as an input and training data sets. The seeds are placed on a white sheet with a distance between the seeds and a camera of 17 inches. The camera used for image acquisition was iPhone 7 plus cellphone with twelve (12) megapixel resolution. For each variety, one hundred (100) images were taken as datasets for training.

The rice seed varieties were grown in different types of lands upland and lowland. They were obtained from the department of agriculture (DA) Regional Office 02. The varieties considered in this research work are; RC 282 (Low land Wet Zone), RC 300 (Low land Wet Zone), RC 392 (General Cultivation), Mestizo (General Cultivation), Java Rice (General Cultivation) RC 23, RC 400, RC 416, RC 152, and RC 346 bot from Low land and a wet zone. Figure 2 shows the rice samples which the researcher uses as data sets for testing.

Figure 2. Rice seed varieties samples

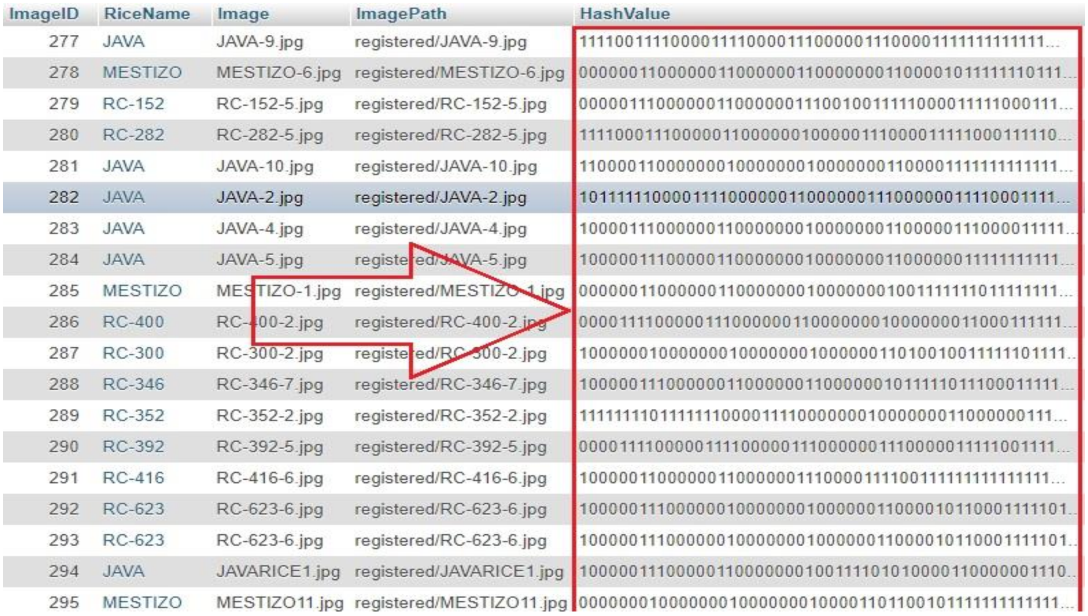
The acquired images are stored as datasets in different folders on the computer, before undergoing image preprocessing for enhancement and segmentation. Image processing and pattern recognition were performed by analyzing the image of rice using computer vision. The phases of image processing activities for the classification process consist of image dataset training, preprocessing and feature extraction, and pattern recognition.

Image dataset training was done to allow the training process of datasets and store the trained image in the database with the corresponding hash value. Hash values of some of the images are shown in Figure 3. Preprocessing and feature extraction allows thresholding activity which converts RGB images to grayscale images which were converted into binary images as internal tracing used in the hashing algorithms. Preprocessing RGB images illustrate the color spaces using three basic components red (R), green (G), and blue (B) in 3-bit spaces. Grayscale is images from conversions of RGB color images into images with small RGB color spaces in 1-bit spaces, conversion of RGB images into grayscale images used the image hash compare which allows partitioning of an image into non-overlapping constituent regions that are homogenous concerning some characteristic of the image such as intensity or texture. Generally, the development process of the grayscale image to produce binary images used (1). Where g (x, y) was the binary image from grayscale image f (x, y) and T was the threshold value. The texture features of rice seeds were extracted using threshold and hashing techniques. The results of the feature extraction from image preprocessing is shown in Figure 4. The initial image shown in Figure 4(a) is converted into a grayscale image shown in Figure 4(b) and then segmented image shown in Figure 4(c) to finally get the hash image shown in Figure 4(d).

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) \geq T \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

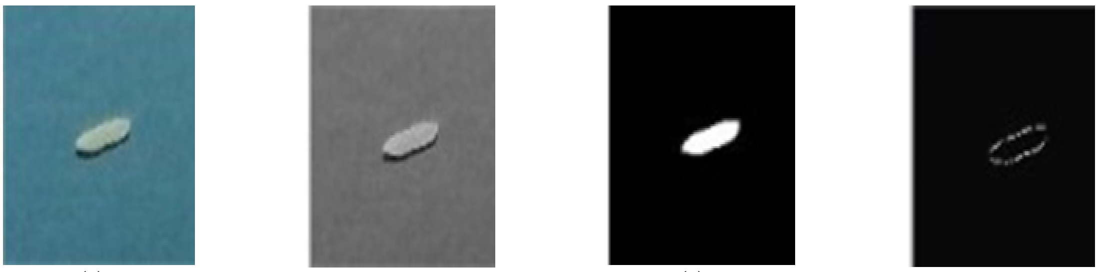
The last process in the image processing activity which is pattern recognition allows the system to reintroduce patterns in the training and testing phase of data sets from feature extraction. An algorithm was used to register and recognize the features of the data sets. Then, image feature analysis was done so that the system extract features to describe different properties of the image. The extracted features consist of three-color features, texture features, and morphological features. The three (3) color features were red, green, and blue (RGB). The features were then taken from the hash value compare image algorithm.

A sample rice seed analyzer classification result is shown in Figure 5. The user will first take a picture of rice seed and save it to the computer. The saved image should be uploaded to the application by clicking the choose file button and selecting the image. When the uploading is done, the user should click on the analyze button and the results will be shown.



ImageID	RiceName	Image	ImagePath	HashValue
277	JAVA	JAVA-9.jpg	registered/JAVA-9.jpg	1111001111000011110000111000001110000111111111111...
278	MESTIZO	MESTIZO-6.jpg	registered/MESTIZO-6.jpg	000000110000000110000000110000000110000101111110111...
279	RC-152	RC-152-5.jpg	registered/RC-152-5.jpg	0000011100000001100000001110010011111000011111000111...
280	RC-282	RC-282-5.jpg	registered/RC-282-5.jpg	1111000111000001100000001000001110000111110001111110...
281	JAVA	JAVA-10.jpg	registered/JAVA-10.jpg	11000011000000001000000010000000110000111111111111...
282	JAVA	JAVA-2.jpg	registered/JAVA-2.jpg	1011111100001111000000011000000111000000011110001111...
283	JAVA	JAVA-4.jpg	registered/JAVA-4.jpg	100001110000000110000000100000001100000111000011111...
284	JAVA	JAVA-5.jpg	registered/JAVA-5.jpg	100000111000000110000000010000000011000000011111111111...
285	MESTIZO	MESTIZO-1.jpg	registered/MESTIZO-1.jpg	000000110000000110000000010000000010011111110111111111...
286	RC-400	RC-400-2.jpg	registered/RC-400-2.jpg	0000111100000011100000000110000000010000000011000111111...
287	RC-300	RC-300-2.jpg	registered/RC-300-2.jpg	100000001000000001000000001000000110100100111111101111...
288	RC-346	RC-346-7.jpg	registered/RC-346-7.jpg	1000001110000000110000000110000001011111011100011111...
289	RC-352	RC-352-2.jpg	registered/RC-352-2.jpg	111111101111111000011110000000010000000011000000111...
290	RC-392	RC-392-5.jpg	registered/RC-392-5.jpg	000011110000001111000000111000000111000000111110011111...
291	RC-416	RC-416-6.jpg	registered/RC-416-6.jpg	10000011000000011000000011100001111001111111111111...
292	RC-623	RC-623-6.jpg	registered/RC-623-6.jpg	100000111000000010000000010000000110000101100011111101...
293	RC-623	RC-623-6.jpg	registered/RC-623-6.jpg	100000111000000010000000010000000110000101100011111101...
294	JAVA	JAVARICE1.jpg	registered/JAVARICE1.jpg	1000001110000011000000001001111010100001100000001110...
295	MESTIZO	MESTIZO11.jpg	registered/MESTIZO11.jpg	00000001000000001000000001000011011001011111111111111...

Figure 3. Trained datasets binarization hash value



(a) (b) (c) (d)

Figure 4. A rice sample’s (a) RGB Image, (b) grayscale image, (c) segmented image, and (d) hash image

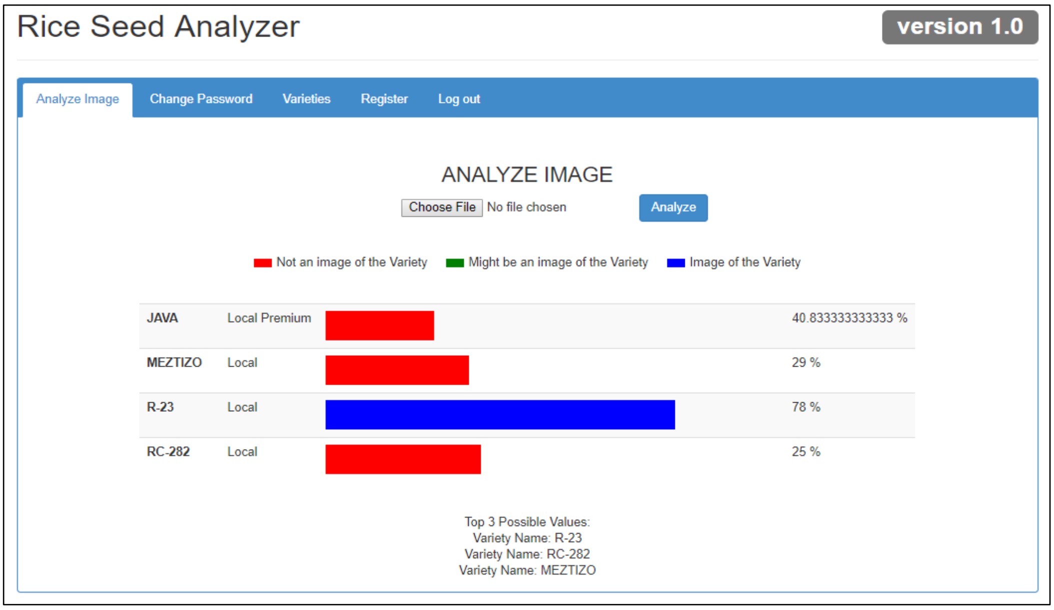


Figure 5. Analyze image results using the rice seed analyzer application

2.2. Respondents of the study

The respondents of this study consisted of seven (7) rice traders, three (3) rice farmers, and ten (10) IT experts. The rice traders and farmers are Tuguegarao City, Solana, and Tabuk. The IT experts consisted of five (5) participants from the Department of Agriculture, three (3) IT Instructors from the University of Saint Louis Tuguegarao, and two (2) free-lance IT practitioners from the industry.

2.3. Research instrument

The questionnaire used in the study is a modified ISO 25010 software quality standards evaluation tool. The modifications were made to suit the needs of the present study. The questionnaire evaluates the overall effectiveness of the rice seed analyzer application. The said tool consists of 16 items which are divided into eight categories which are functional suitability (3 items), performance efficiency (3 items), compatibility (1 item), usability (3 items), reliability (1 item), security (1 item), maintainability (2 items) and portability (2 items) with the following scale: 5=Very Satisfied; 4=Somewhat Satisfied; 3=Neutral; 2=Somewhat Unsatisfied; and 1=Very Unsatisfied. Furthermore, the questionnaire, before its administration to target respondents was checked and validated.

2.4. Data gathering procedure

Before gathering and collecting data, the researcher sought the proper authorization and permission to conduct the research from the Department of Agriculture Regional Office 02 for sample rice seed varieties and rice traders in Tuguegarao, Solana, and Tabuk. Request for proper communication protocol was also observed in the dissemination of questionnaires to rice expert technicians. Procedure in data gathering was used in this research study.

2.5. Data analysis

The data collected in this study were tabulated, analyzed, interpreted, and summarized using both descriptive and inferential statistics based on the given problem statement, and were analyzed using the statistical package for social science for windows (SPSS for Windows). Mean was used to analyze the average rating of the IT experts for the compliance of the application that was developed in this study for the ISO standard using the scale in Table 1. The frequency was used to count the targeted group which was the number of respondents.

Table 1. Qualitative description

Mean Range	Description
4.20 – 5.00	Very great extent (VGE)
3.41 – 4.20	Great extent (GE)
2.60 – 3.39	Moderate extent (ME)
1.80 – 2.59	Little extent (LE)
1.00 – 1.79	Very little extent (VLE)

3. RESULTS AND DISCUSSION

After a series of tests with the 10 different rice varieties involved in the study, this application that applies hashing techniques in image processing had a precision rate is 93.06 percent, with a speed of 8.31 seconds per image. This rice seed classification accuracy is higher than that of previous studies [5]-[9] that use different methods. The mean distribution of the respondent's assessment of the developed system's compliance with ISO 25010 software quality standards is shown in the succeeding table.

The developed system was subjected to assessment and evaluation based on the standards recognized by ISO 25010. The developed system was evaluated as a product in terms of the following criteria as functional suitability, performance efficiency compatibility, usability, reliability, security, maintainability, and portability. Each of these criteria has its respective sub-criteria for more detailed evaluation.

Table 2 shows that the mean assessment of the participants on compliance with the system as to functional suitability ranges from 4.26 to 4.35. The item that is rated highest is "The system is useful in classifying and grading rice seeds varieties". On the other hand, the item that is rated lowest by the participants is "The system can identify the type of rice seed based on a percentage of accuracy". With a total mean score of 4.31, this implies that generally, the system is compliant with the ISO software standards for functional suitability with a descriptive rating of "Very Great Extent". Also, this means score implies that the application adheres to the three characteristics of functional suitability which include functional appropriateness, functional accuracy, and functional suitability compliance [14]. This result can be attributed to the software design used in the development of the system. The software design used serves its purpose which is to convert the specified requirements into prototypes that implement the design into reality [15].

Table 2. ISO 25010 software quality assessment by the respondents to the system

Category	Items	IT Experts	Traders	Farmers	Overall Mean	Category Mean	Description
Functional Suitability	1. The system can classify rice seeds according to their varieties.	4.73	4.29	4.00	4.34	4.31	Very Great Extent
	2. The system can identify the type of rice seed based on a percentage of accuracy.	4.80	4.71	3.33	4.26		
	3. The system is useful in classifying and grading rice seed varieties.	4.67	4.71	3.67	4.35		
Performance Efficiency	1. The system is fast in classifying rice seeds.	4.5	4.43	3.67	4.22	4.34	Very Great Extent
	2. The system can easily generate and Display output.	5.0	4.57	3.67	4.41		
	3. The classification output of the system load smoothly.	4.90	4.14	3.30	4.11		
Compatibility	1. The system can run and display results without affecting other installed applications on my PC.	4.86	4.57	4.33	4.58	4.58	Very Great Extent
Usability	1. The system is simple and easy to use.	4.8	5.0	3.67	4.49	4.39	Very Great Extent
	2. I find the system functioning smoothly and well-integrated.	4.60	4.71	3.67	4.32		
	3. I think the system is accurate and effective for users.	4.60	4.81	3.67	4.36		
Reliability	1. The system can carry out the exact and accurate result with no bugs.	4.86	4.57	4.33	4.58	4.58	Very Great Extent
Security	1. Only authorized administrators and experts can access the system.	4.70	4.14	4.70	4.51	4.51	Very Great Extent
Maintainability	1. The system can be easily set up.	4.7	4.57	3.33	4.22	4.27	Very Great Extent
	2. The system has enough storage capacity to capture an image.	4.70	4.64	3.67	4.33		
Portability	1. I can easily add or remove the captured image in the system.	4.6	4.43	4.00	4.34	4.42	Very Great Extent
	2. The system can display results regardless of the browser am I using.	4.80	4.71	4.00	4.50		

In terms of performance efficiency, Table 2 shows that the mean assessment of the participants ranges from 4.11 to 4.41. The item that is rated highest is "The system can easily generate and display output". On the other hand, the item that is rated lowest by the participants is "The classification output of the system load smoothly". With a total mean score of 4.31, this implies that generally, the system is compliant with the ISO software standards for performance efficiency with a descriptive rating of "Very Great Extent". This is consistent with [16] which stated that software products should be capable of providing the desired performance, relative to the number of resources.

The mean assessment of the participants on compliance with the system as to compatibility has an overall mean of 4.58 and a total mean assessment of 4.58 as presented in Table 2. This implies that generally, the system is compliant with the ISO software standards for compatibility with a descriptive rating of "Very Great Extent". This result shows that the application can exchange information with other systems which is one goal for a system as discussed by [17]. Moreover, the system ensured the compatibility of the interfaces throughout the life of the product [18] based on the result of the assessment.

Table 2 shows that the mean assessment of the participants on compliance with the system as to usability ranges from 4.32 to 4.49. The item that is rated highest is "The system is simple and easy to use". On the other hand, the item that is rated lowest by the participants is "I find the system functioning smoothly and well-integrated". With a total mean score of 4.31, this implies that generally, the system is compliant with the ISO software standards for usability with a descriptive rating of "Very Great Extent". This shows that the application is usable for its target users which is a target attribute for software products as mentioned by [19]. This is a significant finding because many developers have prioritized usability since the users of an application, and their judgment, ultimately determine the success or failure of the application [20]-[22].

The mean assessment of the participants on compliance with the system as to reliability has an overall mean of 4.58 and a total mean assessment of 4.58 as presented in Table 2. This implies that generally, the system is compliant with the ISO software standards for compatibility with a descriptive rating of "Very Great Extent". This indicates that the application, as indicated by [17], carries out specific duties under specific circumstances for a specific amount of time.

Table 2 shows that the mean assessment of the participants on compliance with the system as to security has an overall mean of 4.51. This implies that generally, the system is compliant with the ISO software standards for security with a descriptive rating of "Very Great Extent". This finding also suggests that the application safeguards information and data such that individuals, other goods, or systems have the level of data access relevant to their types and levels of permission, which is a desirable characteristic of a software product [16]. This is a good result since most security specialists try to identify and establish security criteria to protect the overall system from potential harms, threats, and hazards [23].

For maintainability, the mean assessment of the participants on compliance with the system ranges from 4.22 to 4.33 as shown in Table 2. The item that is rated highest is “The system has enough storage capacity to capture image”. On the other hand, the item that is rated lowest by the participants is “The system can be easily set up”. With a total mean score of 4.27, this implies that generally, the system is compliant with the ISO software standards for maintainability with a descriptive rating of “Very Great Extent”. This total mean score shows the degree of effectiveness and efficiency of this application to which it can be modified by the intended maintainers, an important attribute for applications [17]. This assessment result is encouraging since being highly maintainable is essential for reducing approximately 75% of most systems' life cycle costs [24].

The mean assessment of the participants on compliance with the system as to portability ranges from 4.34 to 4.50 as presented in Table 2. The item that is rated highest is “The system can display results regardless of browser am I using.” On the other hand, the item that is rated lowest by the participants is “I can easily add or remove the captured image in the system.” With a total mean score of 4.42, this implies that generally, the system is compliant with the ISO software standards concerning portability with a descriptive rating of “Very Great Extent”. This also implies one of the good characteristics of a software product according to [15] that is the application can be transferred from one hardware. Software developers all agree that software portability is an important aspect of software quality [25]-]27].

4. CONCLUSION

This study developed a rice seed analyzer application that used image processing with the aid of the hashing technique to return good results in classifying the rice seeds. The developed application was fast while being quite accurate. It is fully compliant with ISO software standards and therefore ready for deployment and implementation as evidenced by its high overall performance rating as evaluated by the participants against the ISO 25010.

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REFERENCES

[1] E. Humphreys, S. S. Kukal, E. W. Christen, G. S. Hira, and R. K. Sharma, “Halting the groundwater decline in north-west India-which crop technologies will be winners," *Advances in Agronomy,* vol. 109, pp. 155-217, 2010, doi: 10.1016/S0065-2113(10)09005-X.

[2] D. Kumar and P. Kalita, "Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries," *Foods*, vol. 6, no. 8, pp. 1-22, 2017, doi: 10.3390/foods6010008.

[3] H. Zareiforoush, S. Minaei, M. R. Alizadeh, and A. Banakar. "Qualitative classification of milled rice grains using computer vision and metaheuristic techniques," *J. Food Sci. Technol.,* vol. 53, no. 1, pp. 118-131, 2016, doi: 10.1007/s13197-015-1947-4.

[4] J. F. S. Gomes and F. R. Leta, "Applications of computer vision techniques in the agriculture and food industry: a review," *Eur. Food Res. Technol.,* vol. 235, no. 6, pp. 989-1000, 2012, doi: 10.1007/s00217-012-1844-2.

[5] G. Ajay, M. Suneel, K. K. Kumar and P. S. Prasad, "Quality evaluation of rice grains using morphological methods," *International Journal of Soft Computer Engineering,* vol. 2, no. 6, pp. 35-37, 2013, doi: 10.1.1.301.7950.

[6] H. Kaur and B. Singh, "Classification and grading rice using multi-class SVM," *International Journal of Scientific and Research Publications,* vol. 3, no. 4, pp. 1-5, 2013, doi: 10.1.1.300.7301.

[7] A. Chaugule and S. N. Mali, "Evaluation of texture and shape features for classification of four paddy varieties," *Journal of Engineering*, 2014, doi: 10.1155/2014/617263.

[8] S. Abirami, P. Neelamegam, and H. Kala, "Analysis of rice granules using image processing and neural network pattern recognition tool," *International Journal of Computer Applications,* vol. 96, no. 7, pp. 20-24, 2014, doi: 10.1.1.673.5557.

[9] D. K. Srikanth and A. M. Kavya, "Agricultural crop monitoring using the IOT-a study," *IEEE, 11th International Conference on Intelligent Systems and Control (ISCO),* 2017, pp. 134-139, doi: 10.1109/ISCO.2017.7855968.

[10] P. K. Sethy, K. Santi, S. Dash and A. Pattnaik, "Rice quality evaluation based on image processing: A survey," *Int. J. Inf. Technol. Electr. Eng.,* vol. 8, no. 4, pp. 26-34, 2019.

[11] A. Hussain and E. O. C. Mkpojiogu, "An application of the ISO/IEC 25010 standard in the quality-in use assessment of an online health awareness system," *Jurnal Teknologi, v*ol. 77, no. 5, pp. 9-13, 2015.

[12] H. Karamti, H. Shaiba, and A. M. Mahmoud, “A deep locality-sensitive hashing approach for achieving optimal image retrieval satisfaction,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 3, p. 2526, Jun. 2022, doi: 10.11591/ijece.v12i3.pp2526-2538.

[13] P. Panyapanuwat, S. Kamonsantiroj, and L. Pipanmaekaporn, “Similarity-preserving hash for content-based audio retrieval using unsupervised deep neural networks,” *International Journal of Electrical and Computer Engineering (IJECE),* vol. 11, no. 1, p. 879, Feb. 2021, doi: 10.11591/ijece.v11i1.pp879-891.

[14] A. S. Puspaningrum, S. Rochimah, and R. J. Akbar, "Functional suitability measurement using goal-oriented approach based on ISO/IEC 25010 for academics information system," *Journal of Information Systems Engineering and Business Intelligence*, vol. 3, no. 2, pp. 68-74, 2017, doi: 10.20473/jisebi.3.2.68-74.

[15] K. T. Al-Sarayreh, K. Meridji, M. Alenezi, M. Zarour, and M. D. Al-Majali, "A sustainable procedural method of software design process improvements," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 21, no. 1, pp. 440-449, 2021, doi: 10.11591/ijeecs.v21.i1.pp440-449.

[16] I. Padayachee, P. Kotzé, and A. V. D. Merwe, "ISO 9126 external systems quality characteristics, sub-characteristics and domain specific criteria for evaluating e-Learning systems," *The Southern African Computer Lecturers' Association, University of Pretoria, South Africa,* 2010.

[17] T. Alves, P. Silva, and M.S. Dias, "Applying ISO/IEC 25010 standard to prioritize and solve quality issues of automatic ETL processes," *IEEE, International Conference on Software Maintenance and Evolution,* 2014, pp. 405-412, doi:10.1109/ICSME.2014.98.

[18] M. Zarour and M. Alenezi, "Software process improvement initiative in medium size IT organization: a case study," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS),* vol. 23, no. 1, pp. 500-509, 2021, doi: 10.11591/ijeecs.v23.i1.pp500-509.

[19] E. Abana, "Usability of traysi: A web application for tricycle commuters," *International Journal of Advanced Computer Science and Applications,* vol. 10, no. 7, pp. 280-284, doi: 10.14569/IJACSA.2019.0100738.

[20] P. Weichbroth, "Usability of mobile applications: A systematic literature study," *in IEEE Access*, vol. 8, pp. 55563-55577, 2020, doi: 10.1109/ACCESS.2020.2981892.

[21] H. Feng, T. Hoegler, and W. Stucky, "Exploring the critical success factors for mobile commerce," *in Proc. Int. Conf. Mobile Bus.*, pp. 40, 2006.

[22] E. Garcia-Lopez, A. Garcia-Cabot, C. Manresa-Yee, L. de-Marcos, and C. Pages-Arevalo, "Validation of navigation guidelines for improving usability in the mobile Web," *Comput. Standards Interfaces,* vol. 52, pp. 51–62, 2017.

[23] K. T. Al-Sarayreh, L. Hassan, and K. Almakadmeh, "A trade-off model of software requirements of balancing between security and usability issues," *International Review on Computers and Software (IRECOS)*, vol. 10, no. 12, pp. 1157-1168, 2015.

[24] C. Chen, R. Alfayez, K. Srisopha, B. Boehm, and L. Shi, "Why is it important to measure maintainability and what are the best ways to do it?," *IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C)*, pp. 377-378, 2017, doi: 10.1109/ICSE-C.2017.75.

[25] H. Ghandorh, A. Noorwali, A. B. Nassif, L. F. Capretz, and R. Eagleson, "A systematic literature review for software portability measurement: preliminary results," *9th International Conference on Software and Computer Applications*, pp. 152-157, 2020, doi: 10.1145/3384544.3384569.

[26] N. Haile and J. Altmann, "Evaluating investments in portability and interoperability between software service platforms," *Future Generation Computer Systems*, vol. 78, no. 1, pp.224-241, 2018, doi: 10.1016/j.future.2017.04.040.

[27] A. S. Fathabadi, A. Salehi, M. J. Butler, S. Yang, L. A. Maeda-Nunez, J. Bantock, B. M. Al-Hashimi, and G. V. Merrett, "A model-based framework for software portability and verification in embedded power management systems," *Journal of Systems Architecture*, vol. 82, pp.12-23, 2018.

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