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A Review of Image Processing Techniques for Pest and Disease Early Identification Systems on Modern Cocoa Plantation

Basri[1], Indrabayu[2], Andani Achmad[3] and Intan Sari Areni[3]

[1]*Department of Electrical Engineering, Doctoral Student, Universitas Hasanuddin, Makassar, Indonesia*
[2]*Department of Informatics, Universitas Hasanuddin, Makassar, Indonesia*
[3]*Department of Electrical Engineering, Universitas Hasanuddin, Makassar, Indonesia*

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Abstract: This study presents a potential approach to applying image processing to the cocoa farming industry. Industry 4.0 is changing how technology is applied in cocoa cultivation. Research shows that pests and diseases are major factors that can reduce productivity, especially in the upstream and downstream industries. This study aims to conduct a literature review of several related studies, including previous research. Based on relevant references related to previous research, it is found that the case of disease attack in cocoa is most often studied. This study shows that the color analysis model is more inclined to the case of disease image patterns. The performance pattern of the existing approaches, the average accuracy is 82.85%. More challenges in image processing and efforts are made to improve accuracy but with lower processing complexity. This study also recommends a model that supports the implementation of image processing with machine learning technology in the upstream cocoa cultivation industry. The study results show that the proposed modeling framework can be the following reference for research development towards artificial intelligence technology to support Industry 4.0, particularly in cocoa cultivation.

Keywords: Cocoa, Industry 4.0, Upstream, Pest, Disease

1. INTRODUCTION

Foresight Commodity Services released the potential for the world's cocoa production industry to increase [1]. The demand for quality cocoa beans undoubtedly influences a good cultivation process. Pests and diseases are indeed very significant factors in reasonable cultivation efforts. In contrast to the conventional cultivation process, the scale of the cocoa cultivation industry is now starting to be noticed by investors because of the broad market and the need for processed products from cocoa fruits. The problem in cocoa plantations is crop failure due to pests and diseases [2],[3]. A more modern cocoa cultivation industry should have an integrated monitoring and identification system with artificial intelligence technology. Smart Surveillance system technology in the agricultural sector has been widely applied today. For example, in the cornfield, various sensors combined with drones can widely identify land conditions [4].

The cocoa cultivation industry in the upstream sector with a modern plantation concept requires a monitoring system that can continuously provide up-to-date information regarding the condition of cocoa fruits. Although several previous studies started to use a mobile application, in industrial cultivation, with the huge size of the plantation area, this technology needs to be implemented. Field conditions in monitoring cocoa pods in industrial-scale plantations need to identify the pods' condition carefully. Based on the condition shown in Figure 1, the challenge is how technology can monitor the condition of fruit spacing, identification of ripe fruits, pest attacks, and shadow conditions on fruits clustered on trees. For this reason, technology is needed to connect image processing techniques, IoT, and monitoring control functions without involving much human labor. As part of Industry 4.0, the technology requires data communication network technology with good wireless coverage and services with low delay [5].

Information on pest and disease attacks at an early age on cocoa plantations will certainly be very good for farmers or companies. Prevention and treatment efforts will be much more efficient than if the severe attack conditions on cocoa fruits. With the wide monitoring area and effectiveness and efficiency perspective, applying a drone system for monitoring in the upstream industry is a good solution for farmers or companies that cultivate cocoa. The next

E-mail address: basri21d@student.unhas.ac.id, (indrabayu; andani; intan)@unhas.ac.id

Figure 1. Cocoa fruit conditions that challenge the image recognition system; a. Fruit position on the tree; b. Fruit condition is clear; c. Fruit condition with shady trees; d. Fruit condition is shadowy and disease infested.

problem is the effectiveness of the image processing system from the use of cameras flown using drones and connected to a monitoring system. As a review of recent papers discussed in this study, the concept is very important to be demonstrated so that it becomes the basis for developing the design of technology applications, especially in industrial-based cocoa cultivation.

2. RELATED WORKS

A. Implementation of Smart System on Cocoa Cultivation

The identification systems in the agricultural sector and mobile-based early identification of cocoa fruits have been carried out and widely researched in some evaluations to count cocoa pods on trees using a 4K resolution drone [6]. Identification of defects in cocoa pods using Convolutional Neural Networks (CNN) for image analysis and classification obtained an accuracy rate of (80%) with the model performed by SSD MobileNet V2 [7], determining the quality of cocoa beans [8]. A study with a deep learning model that successfully classifies cocoa pods in static images on trees gave 90% accuracy [9]. Cocoa fruit color is a recognizable pattern [10]. The mobile application for identification with the Deep Learning method using tensor flow module implemented without pre-processing enhanced. Even though implementing mobile with Android applications was very helpful for farmers, accuracy has not been maximized [11]. Previously, to support the research process, a method of classifying the color characteristics of cocoa fruits was carried out by applying Gabor Filtering. The identification of the binary threshold reached better than grayscale data with a difference in the accuracy of 5% [12]. In the case of disease attacks on cocoa fruits, with grayscale images, the maximum results are obtained on training data, with accuracy in the testing process only reaching 70% [12].

B. Pre-Processing Model for Image Quality Improvement

The image processing generally will be optimal if it involves the Pre-Processing process first. The development of image object detection algorithms can be reached in various ways. For example, with Gamma Correction to improve the image quality [13], apply background subtraction techniques, and eliminate noise on image objects [14]. In line with this research, background noise reduction techniques were compared with thresholding techniques and morphological operations to maximize the image identification process with a combination of Convolutional Neural Networks classification. The results showed that the classification results in normal pre-processing with background noise reduction gave better outcomes [15].

Meanwhile, compression, inversion, and line noise removal techniques with Asymmetric least squares (AsLS) and several other approaches have maximized objects in the pre-processing stage [16]. Implementation of image identification techniques in the health sector is also essential for the pre-processing process. Several pre-processing models are introduced to maximize the objects to be identified, including providing high-quality pre-processing objects without treatment manually [17]. Several approaches to improve the Image at the pre-processing stage with a combination of intensity, contrast, and object sharpness, as in [18], show that it can improve visualization objects quality, especially for object recognition underwater.

C. Implementation of Drones for Image Identification

The development of drone technology has now been widely implemented, not just in monitoring but also in identification systems models. Implementing drones in various research fields is also inseparable from the combined modeling. The most basic challenges when using drones in the identification system are camera quality, shooting distance, and disturbances in vibrations caused by the drone engine. In addition, on the image processing side, there are problems with the accuracy of the drone position, the frame rate on the object, and the computational time for extraction [19]. Research that combines drone technology for an object identification system includes an analysis by Amarjot Singh in 2018 that utilized drone technology as a real-time surveillance system. Drones were used only as a vehicle to carry object-monitoring cameras. The implementation of the ScatterNet Hybrid Deep Learning (SHDL) method was used to determine the pose of every detected human movement for further use by SVM to classify violent or non-violent activities [20].

Using drones as a device that carries cameras for object monitoring systems was also used by Markus Küchhold et al. in 2018. This study offers a model of an identification system with a drone camera that was low in terms of the computational process, so it was recommended to be implemented in cases with other embedded systems. The advantage of this modeling was that the zoom variable implemented in a drone's camera with the distance and magnification of the monitoring object could be adjusted and precise [21].

In Agriculture, G. Muley et al. (2020) used drones to monitor plants based on leaf disease characteristics. This research applies RGB pre-processing to HIS format, classified using Tensorflow and complex models for training and identification, AlexNetModel, and CNN for training data. It was found that segmentation and image background as accuracy factors can decrease the similarity of disease objects in leaf images on different species of leaves [22]. The related research above is divided into research in

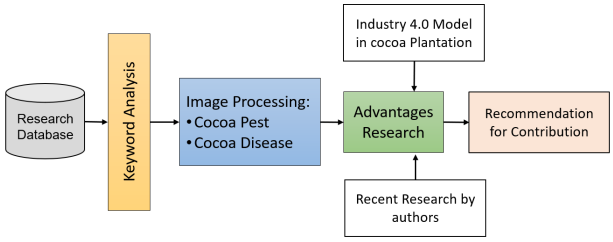

Figure 2. Research Analysis for SOTA

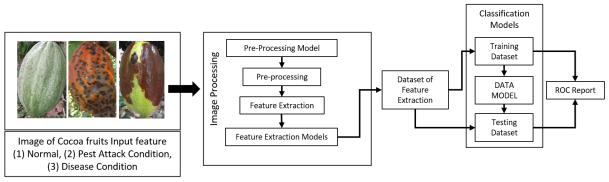

Figure 3. The complete cocoa fruit recognition model

the cultivation sector as an upstream cocoa industry. The novelty offered in this research is possible if the monitoring system uses a drone system. The developed technology can be used on large plantations in modern cocoa farming for pest and disease monitoring attacks on cocoa plantations, especially on fruit. Of course, the new challenge is how the implemented algorithm can maximize the identification system with fast drone movements in its monitoring.

3. METHODOLOGY

This research reviewed several study results that implemented an image-processing system to identify pests and diseases in cocoa fruits. Reference searches were carried out on several recent types of research, and what had been done was then proposed as a potential model to be developed. The classification process recognizes objects into various classes of conditions within the specified threshold value and other conditions according to the required number of classification classes specified at the beginning of image processing.

An overview of the research analysis for State of The Art (SOTA) is shown in Figure 2. Research analysis must reach the advantages of cocoa pest and disease research in image processing. The development model on the latest identification research of pests and diseases of cocoa fruits was carried out by study analysis first. For implementation in Industry 4.0, the cocoa cultivation sector needs to design a SOTA. This approach was carried out by extracting several studies contributing to research development in image processing to identify pests and diseases on cocoa fruits early. State of the Art search of research was conducted to find new challenges in research in this field using the keywords Image Processing, Cocoa Pest, and Cocoa Disease in journals and proceedings from reputable database indexing. The search results were then analyzed to obtain Advantages in research and compared to a recent study by authors and modeling implemented in Industry 4.0.

4. FUNDAMENTAL PROCESS OF IMAGE PROCESSING

Modeling for image identification is generally divided into two stages, namely, the dataset training stage and the testing stage. Image processing in the training dataset section will begin with data acquisition and process object initial state to manually classify objects to be identified. Experts usually carry out this identification process. Various research fields implementing image processing for identification must utilize their expertise. Experts must acquire data with experts because object characteristics must be accurately segmented. The following object classification can be determined by its condition [23]. The results of identifying research related to cocoa are currently more to static images, so the new challenge in image processing is image extraction and data processing from drone videos.

Furthermore, the fundamental process that influences computing-based segmentation is the pre-processing stage, which can be done with various techniques in this approach. Evaluation of the method used will strengthen the features of the object to be classified. Based on Figure 3, several approaches can be applied to this process. Still, good pre-processing techniques will undoubtedly contribute to the limits of the capabilities of the machine learning system applied [15]. The next step is the feature extraction model after the object undergoes pre-processing. This stage will extract the pixel characteristics of the segmented object. The feature Extraction Model is used for further processing by classification techniques. The Feature Extraction algorithm becomes essential to pay attention to in object identification systems with features that are difficult to distinguish from the existing noise.

Even though the segmentation stage can run well, the feature extraction algorithm will ensure that the classified objects can be easily read. Some Feature Extraction Algorithms, for example, use Feature Extraction Algorithms in [24]. Likewise, [25] maximizes the Feature Extraction technique by applying the Neuro-Fuzzy with the Feature Extraction model. After the feature extraction, image processing modeling comes to the classification stage.

5. ANALYSIS OF POTENTIAL CONTRIBUTION

The analysis results from the research database according to the keywords used in the search and the previous research approach found that the results of research data for image processing on identifying pests on cocoa fruits were only two relevant studies. There were eight relevant studies on identifying diseases in cocoa fruits. In addition, with the Industry 4.0 approach to the Model in Cocoa Plantation, applied research that can be implemented is mainly on the application of drones as a monitoring vehicle on plantation land. Research that uses drones in agriculture [26] at least it was stated that 52 research articles report using drones on

plantation land with various uses. Still, nine research results use cameras for monitoring systems that are quite relevant. Identify some of the findings and the potential for research development in the cocoa sector, especially for identifying pests and diseases on fruit with an implementation approach in the cultivation field in Industry 4.0, as shown in Table I.

Table I also showed that from the analysis of previous studies, five Potential Contributions (P.C.) were identified, including Background Subtraction (PC1), pre-processing for increasing accuracy (PC2), Optimization for Algorithms (PC3), Classification Techniques for increasing accuracy (PC4), and drone implementation for pest and disease identification (PC5). All these indications, both the potential for image processing and performance using drones, showed that this research still needs further development, especially developing a pest and disease identification system for cocoa fruits on the cocoa cultivation industry scale.

From Table I, it can be seen that the recent results of previous research had not touched on the implementation of image processing on the cocoa cultivation industrial scale, especially to see the attack of pests and diseases on the cocoa fruits. Even though researchers have implemented image processing with various methods in previous studies, the accuracy was still 70% for pests and 75% for diseases in the Gabor Filter technique [27]. Based on Table I, the potential contribution can be applied to using drones to conduct surveillance in the cocoa plantation area. However, the large real-time video data transmission model requires network transmission resources.

Some of these studies also found that pre-processing was not done first. This research has been done by manually adapting the image color data because it only emphasizes the features of the fruit. For example, it can be seen in the process from previous research shown in Figure 4. The process shows that the study has not implemented pre-processing optimally to strengthen the object characteristics, especially on the features of pest and disease attacks on fruit. This result certainly still has the opportunity to be developed again, especially in the identification system when using the drone in its surveillance system on plantations.

Using Drones as real-time-based surveillance vehicles that monitored plantation land and were even used as a vehicle for watering and controlling pests has been widely implemented. The research using drones, as mentioned above, has implemented the camera function, even in [28], already implemented on plantation land, but to be used to identify cocoa fruits has not been done. It was stated that the use of drones was very risky to the speed of it, so the quality of the focus of image data retrieval will be difficult to do correctly. For this reason, this research has an excellent opportunity when combining several developments of image processing algorithms taken from drones on plantation land. Another novelty was drones, a vehicle that helps farmers (Drone Agriculture) monitor water. Also, further with this research, the technology included in drones will provide information about the condition of plantation land, especially in attacks of pests and diseases, to provide an overview for cocoa cultivation companies to take the following steps.

Considering the use of data models with threshold analysis on pixels is very important to note. Evaluation of the threshold value can affect the results of color pattern accuracy on cocoa fruit infested with pests or diseases. The pixel size of each object gives a different classification depending on the threshold value used. Figure 5 shows how a cocoa fruit image can affect the threshold value used. As in [27], test results showed that the image threshold could produce better results than the grayscale data level. However, the percentage of the two data types shows that the accuracy level is still less than 100%. The image transformation process from RGB to Grayscale for each x,y pixel is executed as formula 1 and each x,y pixel to the binary threshold as formula 2 [29]. This formula in the pre-processing recommendation is needed because the threshold analysis has a lower computational value and can provide a better accuracy analysis value.

$$y = 0.3R + 0.6G + 0.1B \tag{1}$$

$$f(x) = \begin{cases} 1, if f(x,y) \geq T \\ 0, if f(x,y) < T \end{cases} \tag{2}$$

The best accuracy in the pre-processing stage is affected by the color pattern of the cocoa object. As in [43], the feature extraction analysis from 4 models applied to the case of cocoa fruit disease, the selection of color analysis with the HSV technique has a considerable influence. The effect of HSV color analysis on feature extraction is shown in Figure 6.

6. RESEARCH PROPOSE MODEL

Based on the analysis of previous research, Table 1 summarizes both image processing methods implemented in the feature extraction of pests and diseases on cocoa fruits and the potential for its implementation with drones. Based on the analysis of the problems, five potential contributions were obtained, with several approaches that could be solutions, as shown in Table 2. As in the modeling of image processing techniques in Figure 3, the following illustrates the proposed model to implement an early detection system for pests and diseases on cocoa plantations with the industrial 4.0 approach, as shown in Figure 7.

The system design for identifying cocoa fruits attacked by pests and diseases was made in three classification models: normal cocoa fruits condition, diseased cocoa fruits condition, and pest-afflicted cocoa fruits condition. This identification starts from the training phase, where the cocoa

fruits were previously classified based on datasets that experts have tested. The Pre-Processing approach adjusts the applied modeling, then feature extraction and classification are carried out to get the training model. This training model will later be applied to identifying cocoa fruits and their condition on data collection results in real-time using drones. After identification, the condition of cocoa fruits on the plantation with an application-based monitoring system.

The challenge in implementing this technology was the availability of a large broadband network for a network-based IoT system. An alternative solution was placing an Intranet between the drone and the monitoring computer. In addition, another technical obstacle can be a concern when this technology is applied to drones. Lush plantation plants will be difficult for drones to capture real-time fruit objects freely on location.

Strengthening research development, in this case, must be able to maximize the accuracy of the implementation of drones that monitor the real-time condition of cocoa cultivation plantations in the industrial sector. The extent of cocoa plantations with various problems of decreasing productivity will be complicated if done manually. This technological opportunity was used to identify disease and pest attacks on industrial plantations for cocoa cultivation. Still, it can also be integrated with some cases, like a fruit maturity identification system and nutrient deficiencies identification, and the industry can periodically identify potential yields. The approach proposed in this study can provide the best solution as a support system for cocoa plantations in the industrial sector. Initial monitoring with this system will be easily connected to the GPS and localization of the position of objects attacked by pests and diseases so that preventive actions can be taken. Finally, applying the proposed technology can provide a solution for increasing the productivity of cocoa cultivation in the upstream industry.

In addition, based on the investigation of object cases from year to year that implements image processing techniques with various classification model approaches, the following are presented some of the literature review findings in Table III. An overview of the application of several models of image processing algorithms and classification techniques used for performance based on the accuracy obtained is shown in Figure 8.

Based on Table III, image processing cases in research identifying pests and diseases in the past seven years have mostly focused on researching disease attacks on cocoa pods. Algorithm implementation is quite varied, from 10 references related to disease cases. In addition to implementing the Deep Learning method, segmentation with K-Means is also carried out, with quite varied Feature Extraction models, including LBP, GLCM, HSV, and GLCH models. This Feature Extraction indicates that color analysis is more inclined than texture in the case of image patterns in

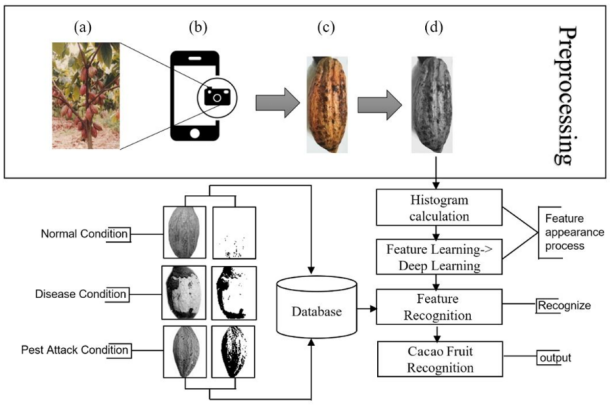

Figure 4. Framework in previous research

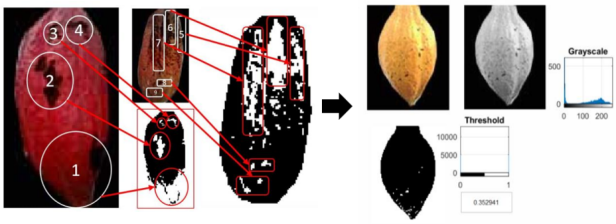

Figure 5. The effect of threshold value[27]

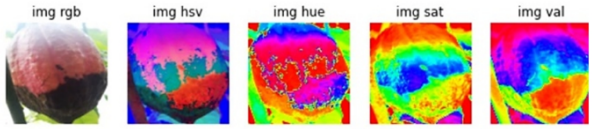

Figure 6. The effect of threshold value[30]

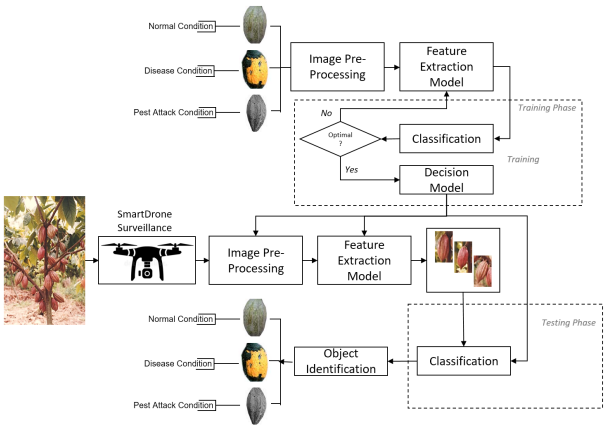

Figure 7. Framework in Proposed Model

TABLE I. Contribution Identification

Ref.	Methodology	Potential Contribution (P.C.)
	Keywords: *cocoa pest, image processing*	
[12]	Identification of Pests on Cocoa Fruit	PC1:Background Subtraction.
[11]	tensor flow module in the deep learning method	PC2:pre-processing for increased accuracy.
	Keywords: *ocoa disease, image processing*	
[10]	Identification of cocoa disease	PC3: Fruit shape localization Algorithm.
[10]	Identification of cocoa disease	PC4: color identification with blobs on the color part.
[27]	image processing techniques on diseased	PC2:pre-processing for increased accuracy.
[31]	Disease Attacks on Cocoa Fruit	PC2:pre-processing for increased accuracy.
[32]	Assessment for Cocoa Black Pod Rot	PC2:pre-processing for increased accuracy.
[33]	predictive data analytics	PC2: pre-processing for increased accuracy.
[34]	tensor flow in the deep learning	PC2:pre-processing for increased accuracy.
[34]	developed with the ResNet18 model	PC2:pre-processing for increased accuracy.
[35]	identify the cocoa tree's diseases	PC4: Classification Techniques for increased accuracy.
	Keywords: *drone agriculture*	
[36],[37], [38],[39], [40],[41], [28],[42]	Using a camera To record visual images	PC5:Implementation of drones for the identification of pests and diseases.
[43]	UAV system for mapping a cocoa field	PC5:Implementation of drones for the identification of pests and diseases.

TABLE II. Potential Models

Ref.	Potential Contribution Cluster	Potential Model
[10],[12]	PC1, PC3 (Feature Extraction Model)	Multi-resolution reconstruction algorithm[44], Hierarchical Feature Extraction Model[45], Convolutional Neural Network[46], Selective multi-convolutional region (SMCR)[46].
[11],[27], [31],[32], [33],[34]	PC2 (Pre-Processing Model)	Model Kombinasi Butterworth low-pass filtering, Butterworth high-pass enhanced filtering, and adaptive weighted median filtering[47], Combination of Median Filter HOG (MHOG) and LBP[48].
[35]	PC4 (Classification Approach)	one-class support vector machines (OC-SVM)[49], Hybrid model Empirical wavelet transform (EWT) dan SVM[49], Hybrid model dynamic reliability measure (DReM) and support vector machines (SVMs)[50], Convolutional Neural Network Model[51].
[36],[37], [38],[39], [40],[41], [28],[42], [43]	PC5 (Drone Implementation)	CNN-multi-task learning with scale-adaptive real-time crowd detection and counting method for drone images (SARCCODI) Model[51].

diseases. The performance pattern of the existing approach, as shown in Figure 8, the average accuracy is 82.85%.

In addition, some previous studies have attempted to implement feature extraction concepts that can improve accuracy. Attempts have been made to process image data with lower resolutions, but the accuracy results still need to be maximized. Therefore, as is generally the challenge in image processing, an attempt is made to increase accuracy but with lower processing complexity. Especially in a framework that implements image processing technology on a drone system for monitoring in the cocoa cultivation industry, it requires a low computational process. Hence, image resolution becomes an issue that needs to be considered. This result is quite positive so that the models used in the study can be implemented with Drone-based concepts

TABLE III. Image Processing Techniques With Various Classification Model Approaches

Ref/ Year	Object	Methods	Contribution
[10]/ 2016	Diseases	K-means (SVM)	Segmentation model, for 35 images, 30 for training, and 5 for testing.
[31]/ 2017	Diseases	Nearest neighbor classifier	using 30 image samples.
[27]/ 2018	Convolution with Gabor Filter	Convolution with Gabor Filter	Comparison of image data models, with cocoa fruit disease on 60 training data and 20 testing data.
[32]/ 2018	Diseases	K-Means, SVM	Disease Level, using 60 datasets of cocoa infected by the disease.
[6] / 2019	Cocoa pods on the tree	K-Means, and BLOB analysis	DFruit Detection Distance Evaluation, with 85 images of cocoa fruit on trees, were taken with three variations of distance, which are 50 cm, 100 cm, and 150 cm.
[12]/ 2019	Pests	Convolution with Gabor Filter	Low-Resolution Image, with 80 image data of cocoa, 60 for training, and 20 for testing.
[11] / 2020	Normal Condition	TensorFlow library	Implementation of Deep Learning for Normal Fruits of Cocoa, with 615 cocoa fruit image data, 176 fruits disease, pest 208 images, and normal 231.
[11] / 2020	Pests	TensorFlow library	Implementation of Deep Learning for Pest Fruits attack of cocoa, with 615 cocoa fruit image data, 176 fruits disease, pest 208 images, and normal 231.
[11] / 2020	Diseases	TensorFlow library	Implementation of Deep Learning for Disease Fruits Attack of Cocoa.
[33] / 2021	Diseases	ResNet18	Phytophthora palmivora identification, using 1596 images in total for training and testing.
[35] / 2021	Diseases	LBP, SVM, RandomForest and ANN	Comparing LBP with several classification models, with healthy and disease condition.
[35] / 2021	Diseases	HOG, SVM, RandomForest and ANN	Comparing HOG with several classification models, with healthy and disease condition.
[30]/ 2022	Diseases	LBP, GLCM, HSV, GCH, SVM	Comparing several feature extraction models with SVM, with 244 image data for the normal class and 173 for the diseased fruit condition class.
[7]/ 2022	Diseases	CNN (SSD MobileNet V2)	They are performing model SSD MobileNet V2, with two types of cocoa diseases (Black Pod and Swollen Shoot) and healthy cocoa.

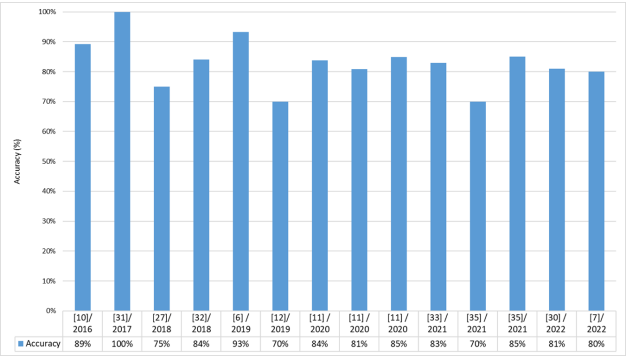

Figure 8. Performance based on the accuracy

in the future as the concept offered in this study.

7. CONCLUSIONS

Based on research analysis conducted from various research references in journal databases and proceedings, it was found that some of the feature extraction processes indicate that color analysis is more inclined than texture in the case of image patterns in diseases. The performance pattern of the existing approach reaches average accuracy is 82.85%. Furthermore, some studies implement image processing and analysis reviews based on keywords. There are 5 Potential Contributions divided into 4 clusters of approaches that become development solutions in image processing techniques, including the Feature Extraction Model, Pre-Processing Model, Classification Approach, and Drone Implementation. This study also proposes several approaches that can be implemented to improve

object feature extraction and further improve object detection accuracy. This study should begin the application of cocoa cultivation in the modern agricultural industry by implementing drones as a real-time surveillance system.

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Basri was born on July 05, 1987, in Polewali, Indonesia. He received a B.E. and M.E degree in Electrical Engineering from Universitas Al Asyariah Mandar (Unasman) Sulawesi Barat (2011) and Universitas Hasanuddin (UNHAS) Makassar (2015), respectively. Currently, he is working on a Doctorate Degree in Engineering at the Universitas Hasanuddin (UNHAS) Makassar. Her research interests are in Multimedia Processing. He is a member of IAENG.

Indrabayu was born on July 16, 1975, in Makassar, Indonesia. He was awarded Summa Cum Laude a Doctoral degree in Artificial Engineering in Civil Application from Universitas Hasanuddin, Makassar, Indonesia, in 2013. Also received an M.E degree in multimedia and communication from Institut Teknologi on November 10, Surabaya, Indonesia, in 2005. He is a Professor at the Department of Informatics, Universitas Hasanuddin. His research interests include Artificial Intelligence and Multimedia Processing.

Intan Sari Areni was born in Watampone, South-Sulawesi, Indonesia, 1975. She received a B.E. and M.E degree in Electrical Engineering from the Universitas Hasanuddin (UNHAS) Makassar (1999) and the University of Gadjah Mada (UGM) Jogjakarta (2002), respectively. She received a Doctorate from Ehime University Japan in 2013. Since 2000 she has been a lecturer in the Electrical Engineering Department, Faculty of Engineering UNHAS. Her research interests include Multimedia Signal Processing, Telecommunication, Wireless and Biomedical Engineering, and Powerline Communication Systems (PLC). She is a member of IEEE and IAENG.

Andani Achmad was born in December 1960. He received his Bachelor's in 1986, Master's in 2000, Doctor in 2010, and Engineer degree from Universitas Hasanuddin. He is a Professor at Electrical Engineering Department, Universitas Hasanuddin. He has several publications in the International Journal with Scopus indexed. Research Interest in Control Systems, Artificial Intelligence, and Telecommunication.