Technology Development for Detecting Palm Oil Ripeness: A Systematic Literature Review

Ryan Alpha August and Suharjito

Department of Computer Science, Binus Graduate Program
Bina Nusantara University, Jakarta, Indonesia
E-mail : ryan.august001@binus.ac.id, suharjito@binus.edu

Abstract

Palm Oil maturity detection technology has developed rapidly. One of the challenges is the difficulty to accurately determine maturity using manual methods. A systematic literature review was carried out. Scientific articles were obtained from journals and analyzed to identify methods which are often used by researchers. Based on the exclusion criteria, 56 papers were included in the analysis. Classification was done according to computer vision and sensors. The results of the literature review indicate that the method widely used by researchers is the Artificial Neural Network (ANN) model. Meanwhile, Near Infra-Red (NIR) was a sensor widely used by researchers as this sensor can measure fruit maturity at an affordable cost. Based on the review, it can be concluded that both computer vision and sensors contribute to accurate and efficient measurement of maturity. Key-words : Computer Vision, Sensor, Predict, Palm Oil Ripeness

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Abstrak

Teknologi pendeteksi kematangan kelapa sawit telah berkembang pesat. Salah satu tantangan saat ini adalah sulitnya menentukan kematangan secara akurat dengan menggunakan metode manual. Sebuah tinjauan literatur sistematis dilakukan. Artikel ilmiah diperoleh dari jurnal dan dianalisis untuk mengidentifikasi metode yang sering digunakan oleh peneliti. Berdasarkan kriteria eksklusi, 56 makalah dimasukkan dalam analisis. Klasifikasi dilakukan menurut visi komputer dan sensor. Hasil kajian pustaka menunjukkan bahwa metode yang banyak digunakan oleh peneliti adalah model Jaringan Syaraf Tiruan (JST). Sedangkan Near Infra-Red (NIR) merupakan sensor yang banyak digunakan oleh para peneliti karena sensor ini dapat mengukur kematangan buah dengan biaya yang terjangkau. Berdasarkan tinjauan, dapat disimpulkan bahwa visi komputer dan sensor berkontribusi pada pengukuran kematangan yang akurat dan efisien.

Kata-kunci : Visi komputer, Sensor, Perkiraan, Kematangan Minyak Sawit.

Introduction

Palm oil is an important commodity in agricultural sector. Indonesia and Malaysia have the biggest production of palm oil in the world. As shown in Figure 1, in 2017 the total palm oil production of Indonesia and Malaysia was 36,000 and 21,000 million metric tons respectively [1]. Indonesia exports palm oil mainly to Asia, the Middle East, Africa and Latin America.

The major problem in the palm oil sector is determining ripeness, which is important to the harvest process, especially to get better quality products, mostly cooking oil. Today, the grading of palm oil ripeness uses human vision as an indicator. As a result, different individuals might have different perspectives. Thus, it is difficult to select fresh palm bunch [2]. Moreover, methods for grading ripeness were still in the trial stage and different methods can impact the grading ripeness process.

Today, technology for determining the ripeness of palm oil has developed rapidly. The main purpose of the palm oil technology is to increase the result grading of the palm oil ripeness. As a result, ripeness can be identified more accurately, reducing time for the selecting process compared to manual methods. This article presents a review of literature focusing on development of technology for detecting the ripeness of palm oil. This review is based on the increasing need for an accurate model for grading ripeness. Moreover, review trends of technology palm oil ripeness will be simply implemen-

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tation which can be applied for farmers.

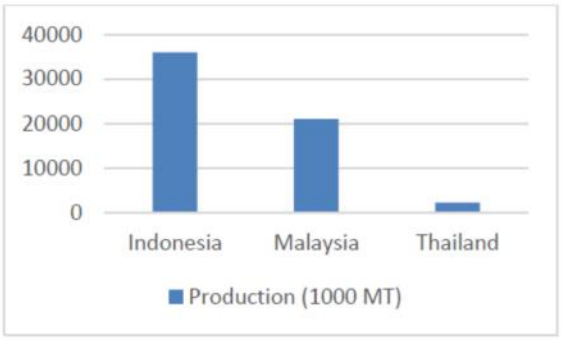

Figure 1: Production Palm Oil (1000 MT) of 2017 [1]

The systematic literature review will provide insights into the right methods for grading ripeness which can be implemented by farmers. Furthermore, it can be used to find tools which detect more efficiently and with low-production cost. As a result, the technology can be implemented in an industrial process. This paper consists of the following sections: section 2 discusses research motivation, Section 3 discusses Research Design, Section 4 presents the Results, Section 5 presents discussions, and section 6 presents conclusions.

Research Motivation

This literature review is based on the variety of maturity, detection methods used. The methods used today are computer vision and sensor. Both methods are being carried out in research which further detects palm oil fruit maturity accurately and efficiently. Therefore, this literature review will find the best methods for grading ripeness. As a result, it facilitates the development of technology in the future.

From all the papers collected, not a single paper presents a systematic literature review of oil palm ripeness. This becomes a gap which provides an opportunity to review future technological developments implemented. Systematic Literature Review (SLR) describes review development technology for grading ripeness palm oil of both computer vision and sensor. Computer vision is basically from artificial intelligence where dataset images of palm oil will be classified to get a prediction base model (i.e. machine learning, deep learning and image processing) meanwhile, sensor is basically from tool device sensor then prediction grading ripeness from sensor methods. The output of this SLR article can provide insights into the various methods used by the researchers in search for the best method for grading ripeness palm oil.

Research Design

In this research design, there are prepared steps to identify the systematic literature review, starting from research question, explaining the question from the research where all the source from papers collected. Literature Search explains the search for a paper journal in a journal database, Study Selection explains the inclusion/exclusion criteria, data extraction, and synthesis.

Research Question

These research questions were developed to get an insight into how many studies focusing on technology development for ripeness of palm oil. the studies were analyzed in terms of the methods aspect. For this study, there are four research questions that were developed:

1. RQ1 – What are the common computer vision techniques used to detect palm oil ripeness?
2. RQ2 – What is the trend of computer vision in the future?
3. RQ3 - How is the development of the sensor method to detect the ripeness of palm oil?
4. RQ4 – What are the challenges of technology development to detect ripeness of palm oil?

Research Stages

The research was conducted based on the following stages in Figure 2:

1. Planning the review:
   (a) Identification of the need for a review, explained main problem will be research.
   (b) Specifying the research questions, explained research the question of main problem.
   (c) Developing a review protocol, explained step research will be carried out.
   (d) Evaluating the review protocol, explained result of research.
2. Conducting the review:
   (a) The identification of primary studies, explained how to collected paper from index journal.
   (b) Selection of primary studies, explained selection the paper according relevant and irrelevant.
   (c) Data extraction and synthesis, explained after paper was selection, it will classification between journal and paper.
   (d) Reporting the review, explained after collected paper, it will analysis according method that used by researcher along research evaluation.

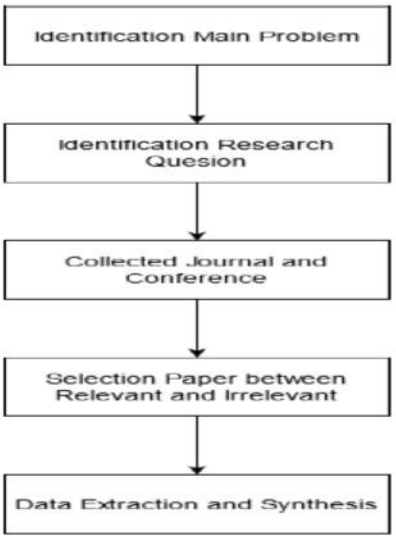

Figure 2: Research Stages of Methodology

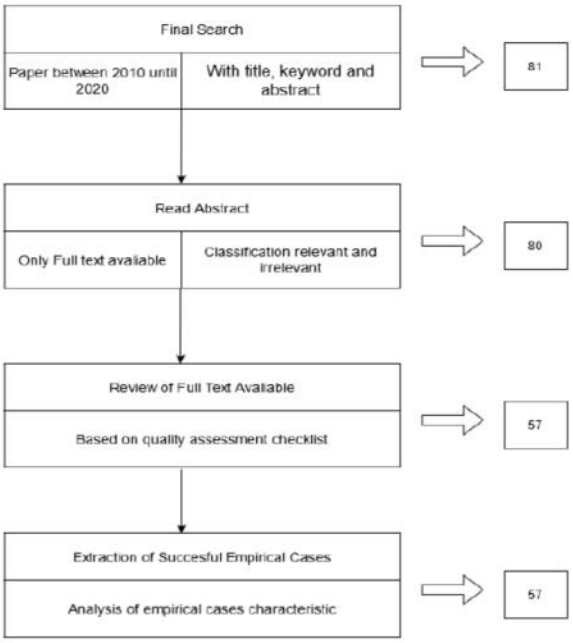

Figure 3: Result of Article Selection

Literature Search

To write a comprehensive literature review, we searched all journal databases from Google scholar and other journal index. The publication years were set to 2010–2020. Our main search was limited to abstracts, keywords and titles to minimize the number of irrelevant hits. Our search string looked for palm oil ripeness AND palm oil, with synonyms or variants of both terms separated by OR operators, as follows: ("palm oil ripeness" OR "palm oil") AND ("image processing" OR "machine learning" OR "deep learning" OR "computer vision" OR "sensor") We searched all databases, including Scopus, Elsevier, ACM, IOP, AIP and CrossRef.

Study Selection

The selection process is illustrated in Figure 3. The author searched all journal databases with the defined search titles, keywords, and abstracts. For databases allowing people to download papers in PDF format, the author wrote a script that automatically aggregated the identification to a spreadsheet of potentially relevant studies.

The final search conducted by the author resulted in 81 studies. All studies were collected according to the year of publication between 2010 and 2020. The second step was reading all the abstracts from this paper to classify the remaining studies to their relevance to the research questions as relevant or irrelevant. In the third step, full-text analyses of papers were done. In this process, quality assessment checklist was used to measure the quality of the papers. From 80 studies collected, only 57 studies were selected for quality assessment. The final step was extraction of empirical cases where the papers were analyzed. The test was conducted according to hypothesis test methods.

Data Extraction and Synthesis

In Table 1, there is the distribution of article data between related and unrelated which will be used the literature review process. Data extraction was done based on titles, keywords and abstracts, continued with a full-text analysis for the final set of 80 included studies. Furthermore, we extracted the following information from the included studies: general (such as authors, information, year and publication target) and research (type, method and sub-method and means of analysis) of the 57 empirical cases among our included set of studies, featured in case studies or experience reports. We also extracted the following information: computer vision model (e.g., image processing, machine learning and deep learning) and sensor methods. The data extracted using the web form was copied to a spreadsheet for data synthesis. Additionally, extracted data from the published reports was also added to the same spreadsheet.

Table 1: Distributed Journal Index

No.	Database	Related	Unrelated
1	ACM	2	0
2	CrossRef	12	1
3	Scopus	19	3
4	Elsevier	6	1
5	IOP	14	1
6	AIP	2	0

Results

Based on the inclusion criteria, 55 articles were collected consisting of 39 journal and 16 conference pa-

pers. As shown in Figure 4, there are publications every year, based on the results of the graph there is an increasing trend of publications on the development of oil palm technology. The main factor in the increasing trend is influenced by the increase in the amount of oil palm yields every year and the latest technology updates have contributed to the increase in the number of publications produced.

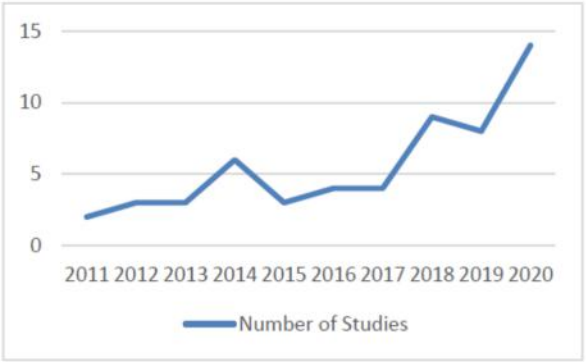

Figure 4: Number of Studies Research According Year Publication

RQ1 – What are the common computer vision techniques used to detect palm oil ripeness?

The application of computer vision for detection of ripeness of palm oil has been categorized by many categories. Furthermore, these studies can be grouped based on three main methods:

1. Image Processing: RGB (Red Green Blue), HSV (Hue-Saturation-Value), YCbCr (Luminance & Chrominance), HSI (Hue, Saturation, Intensity)

2. Machine Learning: Fuzzy Logic, KNN (K-Nearest Neighbourhood), ANN (Artificial Neural Network), SVM (Support Vector Machine)

3. Deep Learning: CNN (Convolutional Neural Network), ResNet (Residual Network), Alexnet

Table 2: Ripeness Palm Oil Model Used in the Studies with Number of Papers.

Type Ripeness Palm Oil	Model	References	Total
Image Processing	Red, Green, Blue (RGB)	[3] [4] [5] [6]	4
	Hue, Saturation, Value (HSV)	[7] [8]	2
	Hue, Saturation, Intensity (HSI)	[2]	1
	Luminance & Chrominance (YCbCr)	[9]	1
Total Paper			8
Machine Learning	Support Vector Machine (SVM)	[5] [10]	2
	Artificial Neural Network (ANN)	[11] [12] [13] [14] [15]	5
	K-Neural Network (K-NN)	[16]	1
	Fuzzy Logic	[17] [18] [19] [20]	4
Total Paper			12
Deep Learning	Convolutional Neural Network (CNN)	[21] [22] [23]	3
	Residual Network (ResNet)	[24] [25]	2
	Alexnet	[26]	1
Total Paper			6

Some studies present results of model computer vision for prediction of the ripeness of palm oil. Table 2 summarizes the techniques used and the number of studies that use each technique. Machine learning is the most widely used method for determining the maturity level of oil palm fruit. Twelve papers discussed techniques using machine learning. From the collected machine learning models, ANN is the model that is often used for determining the maturity of oil palm. Meanwhile, deep learning is a method that is not commonly used. There are 6 study papers that discuss the techniques of deep learning. From the deep learning model collected, CNN is models used in determining the oil palm ripeness.

RQ2 – What is the trend of computer vision in the future?

As Figure 5 explained trends computer vision according year publication. Researcher published experiments using many methods in machine learning. Nevertheless, there are new development models of deep learning which can predict more accurately than both machine learning and deep image

processing. Based on these trends, researcher suggested focus of deep learning methods for future research. A common use of deep learning is research from [23] where the architecture used to measure oil palm ripeness uses CNN. The model applies convolutional which will map the classification of oil palm images, the dataset will go through pooling to go to another convolutional layer for processing by reducing the layer scale to the hidden layer. Furthermore, the hidden layer will be processed by convolutional results based on the type of ripeness, the colour of the fruit drawn and the light saturation. Finally, the output layer performs a data testing process which can determine the type of maturity along with the accuracy of oil palm ripeness.

Based on the above process, CNN has an accuracy rate of 97% when compared to SVM and ANN where both of the average accuracy reaches 70%. The main factor is getting the highest accuracy results compared to other machine learning models. Feature extraction has many convolutional layers that play a role in processing images to classify fruit types. In addition, classification in deep learning has more than one hidden layer which plays a role in classifying the maturity level of oil palm from the results of feature extraction, integration of feature extraction with classification in deep learning can facilitate the classification of oil palm maturity.

Based on the explanation above, deep learning will make further research because the process in deep learning is more accurate, especially with the increasing amount of data, especially un-structed data (i.e. photos, sound and video). Then, compared to machine learning where the feature extraction and classification processes are separate, deep learning processes are integrated with both so that to increase the computational process. Finally, with deep learning, especially the oil palm plantation industry, it can make it easier to harvest fruit that can be used for palm oil so that it can contribute to oil palm farmers.

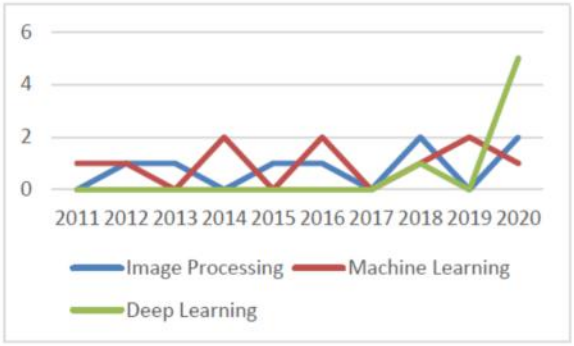

Figure 5: Trends Computer Vision According Year Publication

RQ3 - How is the development of the sensor method to detect the ripeness of palm oil?

In Table 3, there are various types of sensors used to detect the ripeness of oil palm fruit. From the collected sensor methods, NIR is the method commonly applied to oil palm fruit ripeness detection technology. The NIR mechanism uses an infrared system that can determine the composition of the fruit and can detect the level of maturity accurately and efficiently.

Table 3: Ripeness Palm Oil sensor methods used in the studies with number of papers

Sensor Methods	Number of Paper
Microwave [27] [28]	2
Fruit Battery [29] [30] [31]	3
Inductive [32] [33]	2
Near InfraRed (NIR) [34] [35] [36] [37] [38] [39]	6
Optical Sensor [40]	1
Triple Flat [41]	1
Lidar [42]	1
Laser [43] [44]	2
Dual Resonant [45]	1
Spherical steriliser [46]	1
Ultrasonic [47]	1
Photoelectrical [48] [49]	2
Capacitance [50]	1
Optical Spectrometer [51]	1
Optical Probe [52]	1
Bio-speckle [53]	1
Fluorescence [54] [55]	2

RQ4 - What are the challenges of technology development to detect ripeness of palm oil?

There are several challenges of ripeness palm oil depending on the condition, material and model used. For more detail, there are list challenge below:

1. Cost Production: The main important in determining the maturity level of oil palm is the operational costs of the technology implemented. Operational cost can be impact revenue company and cost of maintenance product [48]. Thus, researchers should give solution to the development of palm oil ripeness with high accuracy with lowest cost production as result can be reduce cost operational for development technology ripeness palm oil.

2. Image Dataset: Each dataset of oil palm images collected has different photo quality results. The quality of the photo can affect the accuracy of the maturity of the oil palm thus affecting the yield of the type of maturity. For this reason, photo criteria are needed so that

when taking pictures of oil palm, the photos are clear and sharp

3. Environment: Conditions the oil palm plantation situated and climate in each region affect the quality of the palm fruit. There is a condition in which the occurrence of types of diseases oil palm fruit (i.e. viruses, insects and pests) [56] which causes the quality of oil palm products to be less optimal. In order to get the best oil palm fruit, it is necessary to develop technology which can select types of fresh fruit from the rotten ones as result get quality products.

Discussion

This section provides discussion based on the presented analysis from the review of published articles:

Machine Learning is the most used method for grading palm oil

Based on the three classified methods, machine learning method is a method commonly used by researchers. The mechanism of the method from the dataset is then carried out pre-processing by applying a model from machine learning. The output of the model used can determine which prediction has the highest accuracy. Prediction results on machine learning depend on the model used, the number of datasets and their application in every sector.

Based on the collected machine learning methods, Artificial Neural Network (ANN) has been widely used in research while K-Nearest Neighbourhood (KNN) only has few applications. The researchers are interested in using the ANN model when viewed from the model structure there is a hidden layer which can process the input data [12]. In addition, the application of the ANN model extends to implementation, especially at industrial, business and service scales.

ANN model is applied for grading palm oil

Artificial Neural Network (ANN) model often implemented in everyday cases, ANN architecture consists of three parts: input layer, hidden layer and output layer [12]. The first process starts from the input layer where the data collected will pass through the hidden layer based on the number of nodes inputted by the layer. Then, neural network process was carried out by the hidden layer which will process the data sources obtained based on the number of nodes and finally the output layer is the final process that will get results in the form of decisions and predictions.

The advantages of the ANN model are that it has a faster processing speed and gets the best palm oil accuracy performance [15]. However, the disadvantages of the ANN model is that to get the best results, the dataset must requires image processing first so that in working on the model, it takes longer time for feature extraction to be carried out. In the application of this models, it can be implemented for the oil palm industry, oil palm engineers and oil palm harvesters [13]

Currently, classification of oil palm maturity measured accord on the colour of the oil palm fruit maturity, therefore ANN is a model commonly used in classifying oil palm maturity. As for the implementation of the ANN model used by [13] and [14] implemented the maturity of oil palm by applying sensor devices using the ANN model as a training model, while the results of the process have the above accuracy 85%, while the study of [15] compared the ANN model with the Support Vector Machine (SVM) and K-NN with a higher accuracy rate than SVM and K-NN. Therefore, ANN is a machine learning model that has a broad implementation, especially in classifying the maturity of oil palm.

Deep Learning will be a research trend in the future

Deep learning method will be a research trend in the future due to the various perspectives that require it. In addition, this method is to carry out the prediction process accurately and detail. To reach best result in deep learning need requires a larger number of datasets for pre-processing [24].

The trend of using deep learning will increase in early 2020, where the data is not only structured (text) but is un-structed (i.e. images, video, audio) so that more accurate models are needed in making decisions from datasets. In addition, the increasing application of big data where the process of big data will collect all data transactions from various types of data which is then carried out by a deep learning process in big data so that the processed data will be more efficient in computing and faster in processing [21] [57]. Also, deep learning will make a transformation for future business processes where with the results of processing big data, it can simplify a business decision and make it easier to issue future business budgets appropriately.

NIR is sensory method for detection palm oil

Near Infra-Red (NIR) is a sensor commonly used by researchers, especially in detecting objects. This sensor applies the concept of infrared where the wave emits a target object. The sensor mechanism uses electromagnetism where light can emit waves to the target object thus the wave intensity of the object can be measured. NIR is simple to use, widely applicable and inexpensive. In the detection of oil palm fruit, this sensor does not only function to detect the ripeness of the fruit but can

also measure the oil, moisture and water content of the oil palm fruit easily.

The advantages of NIR Sensory are getting precise accuracy results so that it can help detect the type of palm oil maturity easily. In addition, the cost for such use is cheap and efficient [34]. In the application of the sensor is used to measure the oil and water content in palm oil so as to get the best quality of palm oil [36].

Currently the NIR sensor has been applied to the detection of oil palm fruit, in this research detect the quality of oil palm with a large amount of carotene, this application is carried out by using a spectrometer device connected to the fruit thus it can determine the amount of beta carotene content in palm oil. Meanwhile, researchers detected the level of maturity by comparing the three NIR sensors used by FT-NIR, Micro-NIR and LED-Micro-NIR [34]. Based on these experiments, FT-NIR is the sensor that has the best accuracy in detecting oil palm maturity. Therefore, from the results of this study, the NIR sensor simple to apply to the technology used as industrial needs. As result, it can facilitate the selection of oil palm fruit.

Conclusion

Based on the results of the systematic literature review, it can be concluded that machine learning method is the method most used by researchers and Artificial Neural Network (ANN) is the model mostly used for predicting palm oil ripeness. Meanwhile, Near Infra-Red (NIR) sensor method is a method that is widely used by researchers because NIR can measure the intensity and this method has been widely applied. Both of methods will be assist for palm oil corporate make ripeness process more accurate and clearly rather than manual methods which using human vision. Future research suggestion to applied deep learning as a method that will be implemented frequently. With integrated between mobile, sensory technology with save image dataset in cloud computing, deep learning process make more efficient and reduce complexity time. Further, the dataset of oil palm images should be published to make it simple for other researchers to use the model.

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