Oil palm fresh fruit bunch ripeness classification based on rule-based expert system of ROI image processing technique results

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Abstract. There is a processing need for a fast, easy and accurate classification system for oil palm fruit ripeness. Such a system will be invaluable to farmers and plantation managers who need to sell their oil palm fresh fruit bunch (FFB) for the mill as this will avoid disputes. In this paper, a new approach was developed under the name of expert rules-based system based on the image processing techniques results of the three different oil palm FFB region of interests (ROIs), namely; ROI1 (300x300 pixels), ROI2 (50x50 pixels) and ROI3 (100x100 pixels). The results show that the best rule-based ROIs for statistical colour feature extraction with k-nearest neighbors (KNN) classifier at 94% were chosen as well as the ROIs that indicated results higher than the rule-based outcome, such as the ROIs of statistical colour feature extraction with artificial neural network (ANN) classifier at 94%, were selected for further FFB ripeness inspection system.

1. Introduction

Agricultural product quality conventionally plays a fundamental role in nearly all food industry quality assessments. The traditional method of agricultural product quality assessment is tedious and costly. It is easily influenced by physiological factors, inducing subjective and inconsistent evaluation results[1]. Machine vision provides innovative solutions toward industrial automation [2]. Innovative computer technologies have been utilized in numerous research projects around the world in order to construct new machines for agricultural product quality assessment such as automatic grading systems [3]. The utilization of automatic grading systems for inspection has increased in recent years. Essentially, two inspection stages of the automatic grading system can be identified, viz. external and internal [2,4].

The external grading device is a combination of software and hardware, namely a programming language (PL) and an operating system (OS) with image processing capabilities. The hardware is comprised of a computer, a Charge coupled device (CCD) camera and a data acquisition and conveying system [5-10]. In this paper, rule based expert system (RBES) as a prediction system is proposed and

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implemented with the oil palm FFB ripeness grading system to improve the quality and ensure a high accuracy fresh fruit bunch (FFB) ripeness grading. The proposed RBES algorithm uses the basic concept of rule base, called IF-THEN. The oil palm grading system ripeness grading is implemented with the features and techniques of FFB ripeness without further training and testing. These rules are applied to the different region of interests (ROIs) of the oil palm FFB. The system used the concept of a classifier, which is a function used to assign a class label for the calculation of the probability based on the attribute values that describe an instance [11].

2. Methods and techniques

The classification method RBTES is introduced based on three general steps. First, the experimental result of the FFB ripeness classification based on the supervised machine learning techniques is determined. Second, the rule-based expert system concept [12] is driven using specific ROIs of the oil palm FFB. Third, new rule-based trees are introduced based on the concept of DTs [13, 14] for higher accuracy of the oil palm FFB ripeness grading system, as shown in Figure 1.

![Figure 1. Diagram of the proposed RBES.](image)

2.1. Experimental FFB ripeness classification

Several experiments were conducted on the different models (colour, texture, and thorns) of the oil palm FFB grading system. The ripeness of the three different oil palm FFB ROIs illustrated in Figure 2 was tested with the different feature extraction techniques for each individual model. The three different supervised machine-learning techniques, namely, artificial neural network (ANN), k-nearest neighbours (KNN), and support vector machine (SVM), were implemented with each unique test to investigate and to recognize experimentally the proper methodology for the oil palm FFB ripeness grading system.
2.2. Expert system

The oil palm expert system (knowledge-based system) is a common term used to describe a rule-based processing system, which consists of three elements, namely, database, knowledge base, and interface engine.

2.2.1. Database

A database or working memory is a method to derive data regarding the oil palm FFB ripeness. The oil palm FFB database includes a set of facts used to match against the IF (condition) parts of rules stored in the knowledge base. The oil palm FFB ripeness data were established by the expert of the Malaysian Oil Palm Board (MPOB) based on the study visit done during the early stage of the research. Based on the basic elements illustrated above, the data of the ripeness of the oil palm FFB were experimentally examined, and considered as inputs to the rule-based expert system.

2.2.2. Knowledge base

The knowledge base is defined as the set of if-then-else rules and known facts, which contain the domain knowledge useful for problem solving [15]. In the rule-based expert system of the oil palm FFB, the knowledge is represented as a set of rules. Each rule specifies a relation, recommendation, directive, strategy, or heuristic of the FFB, and has the IF (condition) THEN (action) structure ELSE (action). When the condition part of a rule is satisfied, the rule is decided, and the action part is executed. Since the system has three ROI ripeness inputs, the three inputs of ROIs have three possibilities. Based on the three inputs and one output, there are three rule-based possibilities for each output (under ripe, ripe, and overripe). The $i^{th}$ ($i = 1...3$) rule-based is defined as follows:

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7th \text{ IGRSM International Remote Sensing & GIS Conference and Exhibition } \text{IOP Publishing} \\
\text{IOP Conf. Series: Earth and Environmental Science 20 (2014) 012018 } \text{doi:10.1088/1755-1315/20/1/012018}
\]
IF $r_1$ is $R_1^i$ and $r_2$ is $R_2^i$ and $r_3$ is $R_3^i$, THEN $t_i$ is $T_i(i=1...3)$, ELSE $t_i$ is $T_i(i=2)$

where $r_1$, $r_2$, and $r_3$ denote three input values for ROI1, ROI2, and ROI3, respectively; $t_i$ denotes the output; $R_1^i$, $R_2^i$, and $R_3^i$ ($i=1...3$) denote the three input rule-based for the $i^{th}$ rule that are in (under ripe, ripe and overripe) the three different ROIs, and $T_i(i=1...3)$ denotes the output rule-based of the consequence of the $i^{th}$ rule, which are under ripe, ripe, and overripe.

### 2.2.3. Interface system

An inference system, which contains the reasoning logic, processes the rules and data. The system links the rules given in the knowledge base with the facts provided in the database. Classification and prediction use rule-based algorithms. The rule-based method is a data mining supervisor learning algorithm for performing the classification and the prediction by generating if-then rules that cover all possible cases in a dataset. Finally, the RBES was built based on the close relations of the three different FFB ripeness classes, namely under ripe, ripe, and overripe.

1. The target of the oil palm FFB harvester is the ripe class, which is normally used for palm oil industries due to its reach with oil, lesser water, and fatty acid. By contrast, the under ripe contains much water and the overripe has a high rate of fatty acid.
2. Based on the logic sequence of the ripeness stage, the harvester can harvest the under and overripe classes. However, it is not logical to harvest the under ripe class as overripe class as well as overripe class as under ripe class.
3. Based on the above facts, the expert system rule-based was set as:

**Rule 1:**  
IF \( ROI1 AND ROI2 AND ROI3 \) are OVER RIPE  
OR \( ROI1 AND ROI2 \) are OVER RIPE  
OR \( ROI1 AND ROI3 \) are OVER RIPE  
OR \( ROI2 AND ROI3 \) are OVER RIPE  
THEN FFB is OVER RIPE

**Rule 2:**  
ELSE IF \( ROI1 AND ROI2 AND ROI3 \) are UNDER RIPE  
OR \( ROI1 AND ROI2 \) are UNDER RIPE  
OR \( ROI1 AND ROI3 \) are UNDER RIPE  
OR \( ROI2 AND ROI3 \) are UNDER RIPE  
THEN FFB is UNDER RIPE

**Rule 3:**  
ELSE IF \( ROI1 AND ROI2 AND ROI3 \) are RIPE  
OR \( ROI1 AND ROI2 \) are RIPE  
OR \( ROI1 AND ROI3 \) are RIPE  
OR \( ROI2 AND ROI3 \) are RIPE  
THEN FFB is RIPE

**Rule 4:**  
ELSE FFB is RIPE
3. Results

The RBES is a prediction system proposed and implemented with the oil palm FFB ripeness grading system. The aim of the RBES is to optimize the quality of the oil palm grading system result, and to ensure the high accuracy of the FFB ripeness classification. The RBES algorithm uses a basic rule based on the concept called the IF-THEN-ELSE rule. This rule is based on the facts of oil palm FFB ripeness, and improves the oil palm grading system ripeness implementation with FFB ripeness features and techniques without further training and testing. FFB ripeness is classified in terms of ripeness classes by using a rule-based DT, which considered the differentiation between ROIs.

3.1. ROIs

The concept of the oil palm FFB expert system rule-based DT is based on the three ROIs of the FFB. The expert system was successfully implemented on the ROI ripeness with significant result accuracy. Figure 3 shows the optimization of the Olifera oil palm FFB ripeness grading system based on the ROIs of the colour model with different feature extraction and machine learning techniques.

The best results of the rule-based system were selected for further testing stages. The application of this system on ROIs for statistical colour feature extraction with the KNN classifier reached 93%. The statistical colour feature extraction with the SVM classifier was at 92%, and the colour histogram feature extraction with the SVM classifier was at 92% as well. These findings are shown in Figure 3(a, b, and c). Moreover, the higher result of the ROIs was selected if their results were higher than the rule-based result, such as the ROI1 of statistical colour feature extraction with the ANN classifier at 93%, ROI1 of the colour histogram feature extraction with the KNN classifier at 93%, and ROI3 of the colour histogram feature extraction with the ANN classifier at 94%, as shown in Figure 3(c, d, and f).
4. Conclusion

A new approach was developed under the name of expert rules-based system based on the image processing techniques results of the three different oil palm FFB region of interest (ROIs), namely; ROI1 (300x300 pixels), ROI2 (50x50 pixels) and ROI3 (100x100 pixels). Generally, the results show that the best rule-based ROIs for statistical colour feature extraction with KNN classifier at 94% were chosen as well as the ROIs that indicated results higher than the rule-based outcome, such as the ROIs of statistical colour feature extraction with ANN classifier at 94%, were selected for further FFB ripeness inspection system. The efficiency of the grading rate performance based on rule-based ROIs were significantly higher on the KNN and SVM than the ANN supervised machine learning in all cases. However, the rule-
based system was built based on the different cases of FFB ripeness and provided trusted results despite lesser accuracy than the ROIs.

Table 1. Rule-based results of Olifera FFB of the ROIs test computing based on feature extraction techniques and classifiers.

| Techniques   | FFB ripeness accuracy (%) |   |   |   |
|--------------|---------------------------|---|---|---|
|              | ANN | KNN | SVM |   |   |
| ROI 1        | 93  | 92  | 92  | 92 | 92 |
| ROI 2        | 92  | 90  | 90  | 90 | 90 |
| ROI 3        | 92  | 82  | 82  | 82 | 82 |

Acknowledgement

This research work was supported by University Putra Malaysia (UPM), Geospatial Information Science Research Centre (GISRC), Malaysian Palm Oil Board (MPOB), Ministry of Science, Technology and Innovation (MOSTI) Malaysia.
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