DEVELOPMENT OF SORTING SYSTEM FOR OIL PALM IN VITRO SHOOTS USING MACHINE VISION APPROACH

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By

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There is a promising future for palm oil cultivation because of tissue culture technology that leads to increased production rates as well as enhanced quality. In spite of high demand for palm oil, cheap mass-produced plantlets of oil palm have yet to reach an attractive price. The main reason is that the processing of oil palm tissue culture is still operated manually and is considered too labour-intensive. This affects its economies, especially in developed countries where wages are high. In addition, the plantlet is susceptible to contamination throughout this process. Since a large proportion of manual work is at the in vitro shoots stage, and no commercial automated system for this task presently exists, research will develop a sorting task as a step to reach a fully efficient machine vision system.

This research targets the sorting task which is one of four tasks which have been suggested to achieve greater automation of oil palm tissue culture while in the *in vitro* shoots stages. The four are separation, classification, sorting and rooting. In this work, the type of sample involves oil palm tissue culture (OPTC) shoots obtained from the Malaysia Palm Oil Board (MPOB) tissue culture laboratory. They were acquired, recorded, and utilized throughout the system development. A manual adjusting method for image intensity is here suggested to enhance and sharpen the acquired frames, and the region of interest has been determined as well, which led to simplifying the segmentation and reduce the pre-processing time.

Region-based features, namely area, centroid, aspect ratio, extent and two cropping points have been represented in the shape of OPTC *in vitro* shoots. By using k-means algorithm the extracted features have been evaluated. A smart object tracking algorithm (SOTA) has been proposed for detecting and identifying the shoot on the conveyor belt. Based on SOTA and classification task decision, a sorting algorithm that can acquire, recognize, and eject a shoot has been improved and tested in an offline mode. Furthermore, workable values of external variables and a customized sorter have been designed to test the system in real-time mode and to smooth the ejecting process. Ultimately, the sorting algorithm performance came to be evaluated by support vector machine algorithm.

The performance of the sorting process shows that acquiring, detecting, tracking and sorting functions operate well. The result of K-means has proven the robustness of the selected features. The resulting error of offline tests of the sorting algorithm did not exceed 4.33 per cent. The machine vision system in real-time can eject abnormal shoots from the conveyor, with a limited overall error that could reach as high as 6.6 per cent in the worst case. Close results between the performance of the developed sorting algorithm and SVM algorithm demonstrate that it is satisfactory and efficient. Automating the sorting task was achieved under the main goal which is increasing the production rate and enhancing the quality. In addition, the automated sorting system reduced the overstaffing which achieves part of the economies required to make it of interest in the industry.

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PEMBANGUNAN SISTEM PENGASINGAN UNTUK TUNAS *IN VITRO* KELAPA SAWIT MENGGUNAKAN PENDEKATAN

Oleh

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Industri penanaman kelapa sawit dilihat memiliki masa depan yang cerah disebabkan oleh teknologi kultur tisu yang mampu meningkatkan kadar dan kualiti hasil. Walaupun permintaan terhadap kelapa sawit adalah tinggi, tetapi harga anak pokok kelapa sawit masih berada di tahap yang agak tinggi. Ini adalah disebabkan oleh proses kultur tisu yang dijalankan secara manual dan memerlukan tenaga pekerja yang ramai. Faktor ini menjadikan sector penanaman kelapa sawit sangat tidak memberansangkan dari sudut ekonomi terutamanya di negara-negara maju yang mana kadar upah pekerja adalah tinggi. Selain itu, anak-anak pokok yang diproses secara manual terdedah kepada pelbagai pencemaran yang menjejaskan kualiti pokok. Sebahagian besar daripada kerja-kerja manual ini diperlukan ketika anak-anak pokok berada di peringkat tunas in vitro. Malangnya sehingga ke hari ini, tidak ada satu pun sistem automatik bagi menggantikan tenaga manusia untuk tugasan ini yang telah dikomersialkan. Justeru, kajian ini memfokuskan kepada penghasilan satu sistem automatik untuk proses pengasingan tunas in vitro yang merupakan langkah pertama ke arah satu sistem pengasingan berasaskan penglihatan mesin sepenuhnya yang cekap.

Proses kultur tisu pokok kelapa sawit melibatkan empat peringkat, iaitu pemisahan, klasifikasi, pengasihan, dan percambahan akar. Kajian ini mensasarkan tugasan pengasingan untuk meningkatkan tahap automasi keseluruhan proses. Untuk kajian ini, sampel-sampel tunas kultur tisu kelapa sawit diperoleh dari makmal kultur tisu Lembaga Minyak Sawit Malaysia (LMSM). Tunas-tunas ini telah dirakam, diperoleh, dan digunakan di sepanjang proses pembangunan sistem ini. Kaedah pelarasan kecerahan imej secara manual telah dicadangkan untuk menambah baik kualiti dan menajamkan gambar-gambar yang telah diperolehi. Selain itu, kawasan-kawasan penting atau region of interest (ROI) juga telah ditentukan bagi memudahkan proses segmentasi dan mengurangkan masa pra-pemprosesan.

Ciri-ciri berasaskan kawasan, iaitu keluasan, centroid, nisbah aspek, takat, dan dua titik potongan telah dikenal pasti dan dikeluarkan daripada imej bentuk tunas kultur tisu kelapa sawit. Ciri-ciri ini kemudiannya dinilai menggunakan algoritma k-means. Berdasarkan cirri-ciri ini, satu algoritma menjejak objek pintar atau smart object tracking algorithm (SOTA) telah dicadangkan. Dengan menggabungkan algoritma ini dengan keputusan

klasifikasi, satu algoritma pengasingan yang mampu memperoleh, mengecam, dan melentingkan tunas telah berjaya diperbaiki dan diuji secara luar talian. Sistem ini kemudiannya telah direka bentuk dengan semua pemboleh ubah telah dilaraskan untuk diuji secara masa nyata. Pencapaian sistem ini telah dibandingkan dengan algoritma support vector machine (SVM).

Pencapaian proses pengasingan menunjukan bahawa fungsi-fungsi pemerolehan, pengesanan, penjejakan, dan pengasingan telah berjalan dengan baik. Keputusan K-means pula telah membuktikan bahawa ciri-ciri yang telah dipilih adalah teguh. Ralat-ralat yang diperoleh daripada ujian luar talian terhadap algoritma pengasingan juga tidak melebihi 4.33 peratus. Sistem penglihatan mesin yang beroperasi dalam masa nyata mampu melentingkan tunas yang tidak normal keluar dari tali sawat penghantar dengan ralat keseluruhan hanya 6.6 peratus. Keputusan ujian terhadap algoritma yang telah dicadangkan ini adalah hampir menyamai dengan keputusan yang dicapai oleh algoritma SVM, seterusnya membuktikan bahawa sistem ini adalah cekap dan memuaskan. Secara keseluruhannya, pengautomatikan sistem pengasingan tunas kultur tisu kelapa sawit ini telah mencapai objektif utamanya, iaitu untuk meningkatkan kadar dan kualiti pengeluaran kelapa sawit. Tambahan pula, sistem ini mampu mengurangkan kos pengambilan pekerja, menjadikanya satu pilihan yang menarik dari sudut ekonomi.

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LIST OF ABBREVIATIONS

MPOB	Malaysian Palm Oil Board
ARR	Applied Agricultural Resources Sdn. Bhd
AVI	Audio Video Interleaved
HMM5	Hidden Markov Model
LOOCV	Leave-one-out cross-validation
OPTC	Oil Palm Tissue Culture
ROI	Region of Interest
SOTA	Smart Object Tracking Algorithm
W4	Who? When? Where? What?
SVM	Support Vector Machine

CHAPTER 1

INTRODUCTION

1.1 Overview

The oil palm tree produces edible oil that is widely known in commercial agriculture production as one of the healthy vegetable oils. Oil palm and palm oil manufacturing are considered as effective factors in terms of national economies in many countries. Forty-two (42) countries' palm oil production accounts for 34 per cent of world's annual production of vegetable oils and 63 per cent of the global exports of vegetable oils. In Nigeria, the oil palm industry offers a chance for millions of unskilled and semi-skilled labourers to be employed [1] and in Malaysia the palm oil industry "provides [a] job opportunity directly to 500 thousand people and indirectly to 2 million people." At the end of 1960, there were about 123,000 ha of oil palm in Malaysia and at the end of 2004, there were around 3.87m ha producing 13.9m tons of crude palm oil. Today, to raise the productivity by extending the planted land is not suitable because of multiple uses land and its many purposes. To keep and increase high-yielding palm oil, the only effective method is to increase the oil yield per hectare on the same planting area [2,3].

Plant tissue culture technology is the most suitable way to raise the productivity of crude oil palm per hectare. The production of high quality, disease-free and uniform planting material leads to high-yielding farming. For instance, Applied Agricultural Resources Sdn. Bhd (ARR) is one of the largest Tissue Culture Laboratories in Malaysia. Its oil palm clone can produce up to 10.6 t/ha/year of crude palm oil, which is 20-25% higher than the yield of conventional seedlings. This has allowed tissue cultured plants to reach many developed and developing countries. However, the technology of tissue culture is expensive compare to conventional methods. Among all the factors that cause the high cost of the OPTC production, labour is the prime factor in developed countries. Due to those costs, researchers have been tried to partially automate some steps to reduce the process cost [2].

Many oil palm tissue culture [OPTC] laboratories in several countries still use a quality of production and raises the cost because tissue culture is a labour-intensive process. Since there is high-demand for tissue cultured plants, there is enormous need to automate those operations done by hand. The high sophistication of the machine vision field offers possibilities to engineer an optimum system to facilitate the selection process and optimise its quality control.

1.2 Problem Statement

Tissue culture allows improvement in quality and production rate for numerous agricultural products. However, OPTC is a labour-intensive process, and results in high-costs for tissue culture technology, especially in developed countries. To reduce the cost of production, labour-intensive steps in this process should be automated whenever possible. The tissue culture process is usually divided into five stages and according to Debergh and Maene, 1981. [4] Stage III of *in vitro* (shooting and rooting of the explants) accounts for 35-75% of the total production cost because it is a labour-intensive stage. Automating this stage will not only reduce the cost, it will also raise production rates of tissue culture plants. A classification algorithm has already been developed [5] to classify the shoots into normal and abnormal. For applying the classification algorithm in real time, a sorting system is required.

The difficulty of OPTC automation is caused by genetic, physical and economic factors. The process should be in an aseptic environment, and the shoots in this stage are easily damaged by touching. The shoots have flat, thin and ill-defined shapes, sizes, and dimensions making the mechanical handling (cutting, rooting, and sorting) a complicated task. The intention of this research is to suggest an economical sorting system where the classification algorithm could be applied in real time. The research reported here has resulted in an image-processing algorithm that can detect shoots on the conveyor and use a suitably designed tool for ejecting abnormal ones from a conveyor depending on the classification algorithms.

1.3 Research aims and objectives

In the manual sorting process of OPTC shoots, the skilled workers have enough experience to categorize the shoots. They can sort out the abnormal shoots from normal ones. This research has developed an image-processing algorithm to detect the arrival of a shoot on the conveyor when it is entirely within the field-of-view of camera. At the same time it generates a signal which controls a mechanical tool that ejects the abnormal shoot off of the conveyor depending on the classification algorithm decision available from related research. The objectives of the current research can be summarized as follows:

1. To develop a sorting algorithm able to detect, track, identify and eject the coming shoot on conveyor and testing its performance in both real-time and off-line simulation modes.
2. To develop an *in vitro* shoots dataset based on region-based features to be used in improving an effective tracking of OPTC samples coming along the conveyor.
3. To build a suitable tracking algorithm that can ensure a fast detecting and tracking of OPTC samples in successive frames.

1.4 Scope of Work

The research will concentrate only on the sorting at the shoots' development stage of the oil palm tissue culture, which will eject abnormal shoots out of the conveyor depending on the decision of the classification algorithm reached previously in related research [5]. The speed of conveyor is considered a dependent variable ranging from 4 cm/s to 10 cm/s, and it must be set by the operator during the process. The research assumes that the feeding operation was done manually and considers that there is distance between the samples (OPTC shoots) during conveyor feeding.

1.5 Thesis Outline

The first chapter in this research introduces the POTC and the massive need of a full automation system in order to substitute manual operations at the stage III of tissue culture shoots. The research problem, objectives, aims and limitation are also presented in this chapter. In chapter two, the review of the literature begins with a short introduction of the OPTC process and its stages. After that, an in-depth revision of previous machine vision systems is discussed as well as the most important technics such as detection and tracking.

The chapter three explains the research methodology. It starts by introducing the data collection process for creating a database followed by acquiring data conditions and image pre-processing. The latter includes adjusting image intensity, choosing ROI, thresholding and extracting features. The sorting algorithm depending on SOTA has been discussed. At the close of this chapter, a sorter design for ejecting abnormal shoots is been introduced. In the results and discussion chapter, the results of the sorting algorithm as well as SOTA performances are presented. The results of the sorting algorithm are shown in tables and also with graphical representations as they help in visualizing the results. In the last chapter, some technical problems encountered during this research are discussed along with suggestions for overcoming them.

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