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PREDICTING CHLOROPHYLL INTENSITY OF VARIOUS PLANTS USING IMPROVED CONVOLUTION NEURAL NETWORK

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Bachelor of Engineering

Electrical and Electronics Engineering with Honours

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PREDICTING CHLOROPHYLL INTENSITY OF VARIOUS PLANTS USING IMPROVED CONVOLUTIONAL NEURAL NETWORK

MICHELLE NASHRIN BAWAI

A dissertation submitted in partial fulfilment
of the requirement for the degree of
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ABSTRACT

Chlorophyll pigment is beneficial during photosynthesis to absorb sufficient light energy and provide nutrients to the plant to grow healthy. A convenient assessment of chlorophyll content is essential in smart management agriculture. Several attempts have been made to implements computer vision to enhance the precision agriculture techniques. However, problems still arise as the applied algorithms of machine learning are time consuming, very complex architectures, high computational cost, as well as less generalization towards various plant species and size of datasets. Hence, in this project, a rapid and straightforward convolutional neural network (CNN) algorithm was proposed to predict chlorophyll intensity of various plant species based on leaf reflectance spectra. The datasets were taken from ANGERS Leaf Optical Properties Database (2003). The proposed model consists of Hybrid CNN as a feature extractor and support vector regression (SVR) network as a predictor. Hybrid CNN was designed by modifying the architectures of AlexNet and PNet using MATLAB R2023a. The performance of Hybrid CNN with SVR (CNN-SVR) was also compared with AlexNet, PNet, and SVR. Results showed that the best CNN also can be designed with one input, four convolutional, four max-pooling and three fully connected layers which can be found in Hybrid CNN-SVR. The experimental results show that the prediction accuracy of chlorophyll intensity is satisfying with a mean square error (MSE) of 0.1558 and 1.149 for training and testing sets, respectively.

ABSTRAK

Pigmen klorofil bermanfaat semasa proses fotosintesis untuk menyerap tenaga cahaya yang mencukupi dan membekalkan nutrien kepada tumbuhan untuk bertumbuh dengan sihat. Penilaian kandungan klorofil yang mudah adalah penting dalam pengurusan pertanian yang tepat. Beberapa percubaan telah dibuat dalam melaksanakan visi komputer untuk meningkatkan teknik ketepatan pertanian. Walau bagaimanapun, masalah masih timbul kerana algoritma pemelajaran mesin yang digunakan memakan masa, struktur yang sangat kompleks, kos komputasi yang tinggi, serta kurang generalisasi kepada pelbagai spesies tumbuhan dan saiz set data. Oleh itu, dalam projek ini, algoritma rangkaian neural berlingkaran (CNN) yang pantas dan mudah telah direka untuk meramalkan kandungan klorofil dalam pelbagai spesies tumbuhan berdasarkan spektrum pemantulan daun. Dataset diambil dari Pangkalan Data Harta Optik Daun ANGERS (2003). Model yang terlibat adalah Hybrid CNN sebagai pengekstrak ciri dan rangkaian regresi vektor sokongan (SVR) sebagai peramal. Hibrid CNN direka bentuk dengan mengubah suai seni bina AlexNet dan PNet menggunakan MATLAB R2023a. Prestasi Hibrid CNN dengan SVR (CNN-SVR) juga dibandingkan dengan AlexNet, PNet dan SVR. Hasil analysis menunjukkan bahawa CNN terbaik juga dapat direka bentuk dengan satu input, empat convolutional, empat max-pooling dan tiga lapisan sambungan penuh yang boleh didapati dalam Hybrid CNN-SVR. Keputusan eksperimen menunjukkan bahawa ketepatan ramalan kandungan klorofil adalah memuaskan dengan ralat min kuasa dua (MSE) masing-masing 0.1558 dan 1.149 untuk set latihan dan ujian.

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LIST OF EQUATIONS

LIST OF ABBREVIATIONS

1D	-	One-Dimensional
3D	-	Three-Dimensional
Adam	-	Adaptive Momentum Estimation Optimizer
ANN	-	Artificial Neural Network
BP	-	Back Propagation
BPNN	-	Back Propagation Neural Network
CNN	-	Conventional Neural Network
CNN-SVR	-	Conventional Neural Network with Support Vector Regression
CO_2	-	Carbon Dioxide Gas
FDA	-	Fisher Linear Discriminant Analysis
FYP1	-	Final Year Project 1
FYP2	-	Final Year Project 2
INRA	-	Institution for Agriculture Research
LCC	-	Leaf Chlorophyll Content
LCD	-	Liquid Crystal Display
LDA	-	Linear Discriminant Analysis
LED	-	Light-Emitting Diode
MAE	-	Mean Absolute Error
MATLAB	-	Matrix Laboratory
MLP	-	Multi-Layer Perceptron
MSE	-	Mean Square Error
nm	-	nanometer
ODbL	-	Open Database License

PCA	-	Principle Component Analysis
RBF	-	Radial Basis Function
ReLU	-	Rectified Linear Unit
RF	-	Random Forest
RMSProp	-	Root Mean Squared Propagation
SGDM	-	Stochastic Gradient Descent with Momentum
SPAD	-	Soil Plant Analysis Development
SVM	-	Support Vector Machine
SVR	-	Support Vector Regression
USDA	-	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Background

Every plant contains vital green pigments known as chlorophyll which can indicate the concentration of the elements for the synthesis of chlorophyll such as nitrogen, iron, and magnesium [1][4]. Furthermore, chlorophyll is beneficial during photosynthesis to absorb sufficient light energy and provide nutrients to the plant. Thus, the crop diseases and yield predictions are assuredly assessed depending on the intensity of the green pigments in the leaves [5].

Various advanced computer technological methods have been proposed previously to predict the intensity of chlorophyll based on the plant leaves. Conventional methods for chlorophyll intensity prediction are either destructive or non-destructive [5]. For the destructive method, the pigments are crushed and extracted from the leaf sample using solvent extraction and subsequent spectroscopic chlorophyll analysis. However, this method needs cautious disposal of the extraction solvent waste, the high number of samples required, and the estimation parameters are restricted and time consuming [6].

Meanwhile, for the non-destructive method, the chlorophyll intensity is quantified by using specialised devices such as chlorophyll fluorescence [6], spectrometer [7], and Soil Plant Analysis Development (SPAD) [8]. These methods are categorised as conventional non-destructive measurement devices. The measurement of chlorophyll intensity using these conventional methods are mainly done by analysing the leaf surface without destroying the samples. Nonetheless, the devices required large samples to maintain culture sterility [6], as well as are still costly and difficult in generating reflectance spectrum data for both personal and commercial purposes. Due to these reasons, several alternative with advanced non-destructive approaches were developed to reduce the involvement of massive labour and rapid progress.

In previous studies, Artificial Neural Network (ANN) is commonly applied for commercial agricultural purposes in order to predict leaf area, classify the leaf and predict the crops yield, chlorophyll content quantification and fruits weight [2]-[4]. It is also widely used due to the higher accuracy in deciding the prediction results based on the digital image data of the plants [5]. The architecture of ANN consists of three layers of processes which are the input layer, the implicit layers, and the output layer. Nonetheless, as the development of machine learning approaches is getting fast to be improved, there are several drawbacks discovered in the application of ANN for agricultural field. For instance, feature extraction task is much complicated as the developer needs to manually design the best features using raw digital image data [7].

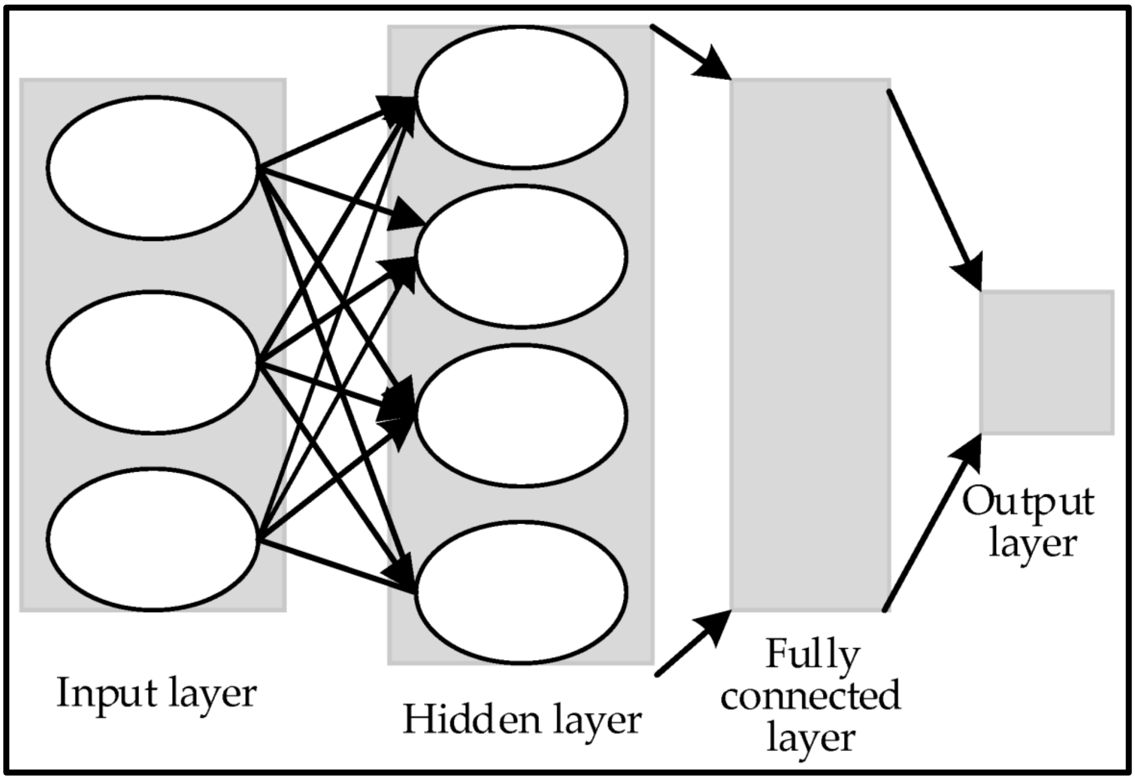

Figure 1.1: General Convolutional Neural Network Structure Diagram [6]

Therefore, ANN model is less automated compared to the famous architecture deep learning which is Conventional Neural Network (CNN) model. CNN model can reduce the developer's effort and knowledge limitations in designing the feature extraction. Morphological image segmentation led directly to the term of convolutional. A convolutional matrix is used to detect edges, blur, and sharpen an image [7]. In recent studies, the algorithms of CNN on plant were mainly aiming the nutrient deficiency [9], species classification [10], disease and health detection [9],[10], and photosynthetic pigments quantification [13] based on digital images and reflectance spectra data.

CNN commonly is utilized to handle digital image data with two or three dimensions. Based a previous study, photosynthetic pigments of a plant have been predicted by processing plant leaves digital images using CNN. Hence, CNN can produce simultaneous predictions of the three different pigment contents including chlorophyll, carotenoid, and anthocyanin. The results showed that the performance of CNN is remarkable in representing the relationship of non-linear models between the photosynthetic pigment contents and its plant digital images. Leaf reflectance spectrum is a one-dimensional (1D) data [12].

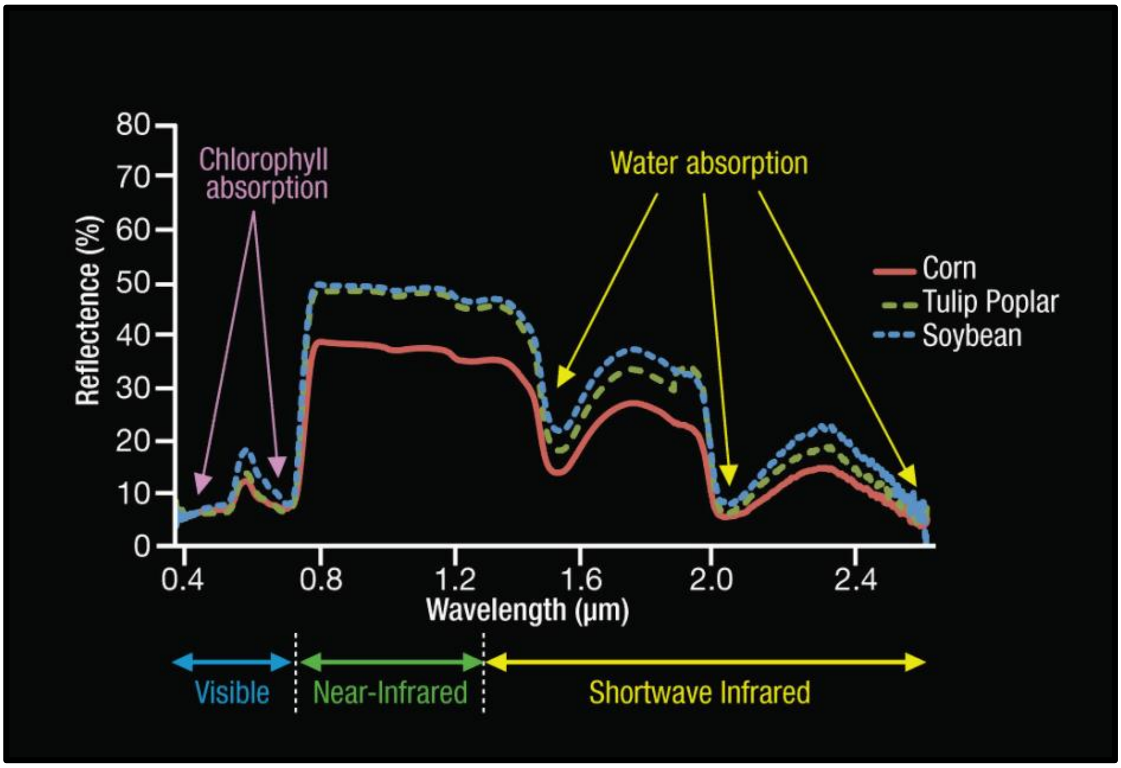

Figure 1.2: General Leaf Spectra based on Light Absorption (Image credits: Eric Brown de Colstoun)

CNN have certain accuracy and generalization in many domains and have the potential to solve problems stated. CNN has the difficulty in designing the optimal architecture as the accuracy of CNN is determined by CNN architecture in terms of its kernel sizes, number of layers, types of layers and connection sequence of these layers. However, this concern can be solved with number of finding, readings, and understanding [13]related to the prediction techniques of this photosynthetic pigment so an effectively and user-friendly system can be utilized easily as well as, giving the contribution to agriculture industry.

In this research, a non-destructive and real-time model of CNN is proposed as a main tool to predict the intensity of chlorophyll content.

1.2 Problem Statement

Recently, plant physiological has been triggered by climate warming. It affects the physiological processes in plants such as photosynthesis, respiration, and decomposition. The recent temperature predictions of 2 °C until 5 °C warming is most likely experienced by many plants in the ecosystem [14]. Thus, the plants have to make immediate physiological adjustments toward warmer conditions in order to maintain the gain of carbon. However, plants do have its own considerable capacities that can affect their growths. Warmer climates have led the plants to reduce their growth, photosynthetic capacity, carbon gain, and respiration rates. Therefore, the intensity of chlorophyll content affects the production of carbon dioxide (CO_2). Figure 1.3 shows the illustration of affected respiration and photosynthesis rates as the temperature is getting warmer which increased the rate of CO_2 exchange in the atmosphere.

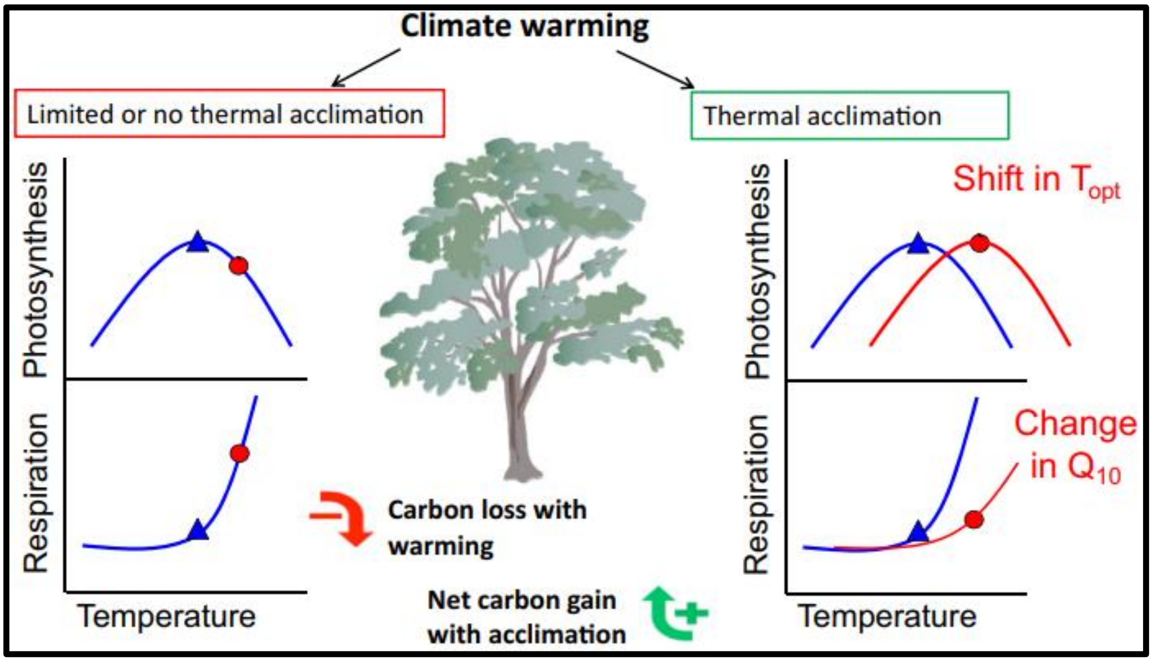

Figure 1.3: Affected Respiration and Photosynthesis Rates as Climate Warming is Increasing [14]