Research Article

A MATLAB Graphical User Interface for Intelligent Characterization of Oil Palm Fruitlets

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Abstract

User-friendliness and ease-of-usage are two of the important qualities of a good measurement and characterization system. This work attempts to bring these qualities into the characterization of oil palm fruitlets for easier grading. Measurement of microwave energy parameters was first carried out on clean and ripe samples of oil palm fruitlets within the frequency range of 2-4GHz. The dielectric properties of the fruitlets were extracted from the values of the measured parameters and an intelligent Artificial Neural Network was designed and trained for prediction of the percentage oil content of the fruitlets. This network was linked to a carefully designed Graphical User Interface (GUI) written on MATLAB platform. Results of this work established that the prediction accuracy of the Neural Network-linked GUI is high and serves as a reliable tool for rapid determination of the quality of oil palm fruitlets. Additionally, the GUI served as a tool which helps users to efficiently characterize oil palm fruitlets with particular application in research and quality control.

Keywords: Graphical User Interface (GUI), Artificial Neural Network, oil content, oil palm fruitlets, dielectric properties.

1. Introduction

First principle derivation and computation of dielectric properties of materials from laboratory electromagnetic measurement is a difficult task due to the involvement of triple integrations, multiple iterations and optimization (Adedayo *et al.,* 2014). For example, when attempting to compute the complex permittivity of a sample under test from measured values of the reflection coefficient, the ideal requirement would be the direct computation of the complex permittivity for the specified reflection coefficient. Unfortunately, the inverse solution cannot be solved directly which necessitates interpolation or optimization routine (Gershon *et al.*, 1999).

The advent of computers and the increasing technical knowledge base in programming and computing has been harnessed by researchers in proffering solutions to otherwise complex technical and day-to-day problems especially in the optimization domain. These have been widely documented in a wide range of applications and fields. However, more prominently in the last few decades, researchers tend to present their findings in a more compact and user friendly format, improving the ease of usage and applicability of the research findings and solutions. A

reason for this shift is that conventional presentation is not only time consuming, but also prone to user induced inconsistency when individuals utilize different criteria for important variable definitions. To overcome these challenges, researchers often prefer to develop user friendly, graphical user interfaces (GUIs) often programmed in the MATLAB platform, allowing users to efficiently, rapidly and reproducibly perform intended processes (Dillon *et al.*, 2015)

An example of such integration in fluid mechanics is the development of a MATLAB based graphical user interface to compute the translational diffusion coefficients in three dimensions for a single diffusing particle, suspended inside a fluid (Charsooghi, *et al.*, 2011). Similarly, in Power Engineering, the design of a software package, called VS&OP, for power system engineering and power system courses at the graduate and undergraduate levels have been reported (Gozel *et al.*, 2008). Similar developments have also been reported in research and development, learning and training (Hafizi *et al.*, 2013; Jaumot *et al.*, 2005; Mohallem *et al.*, 2012; Tansel *et al.*, 2014; Bucha & Janak, 2014), and in Medical instrumentation and imaging (He *et al.*, 2011; Alakhdar-mohmara *et al.*, 2012, Vousdoukas *et al.*, 2012).

This work therefore reports the development of a MATLAB based GUI for a well-trained Layer Sensitivity

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Based Artificial Neural Network (LSB-ANN) for nondestructive characterization of oil palm fruitlets.

2. Extraction of Dielectric Properties for Samples

In order to accurately characterize the oil palm fruitlets from the values of measured parameters, the values must be fitted into appropriate dielectric models depending on the sample size, sensor dimension, and the frequency in use.

One of the most frequently used extraction techniques is the admittance model in which two relations for the analysis of TEM waves for the admittance of a coaxial probe are expanded, that is:

$$Y = j \frac{k^2 Y_0}{\pi k_c \ln\left(\frac{b}{a}\right)} \int_a^b \int_a^b \int_0^\pi \cos\phi' \frac{e^{-jkr}}{r} d\phi' d\rho' d\rho \qquad (1)$$

where Y_0 is the characteristic admittance of the line in use. The wave pattern has a magnetic field component along the azimuthal direction ϕ, and an electric field component along the radial direction ρ and,

$$r = \sqrt{(\rho^2 + \rho'^2 - 2\rho\rho' \cos\phi')} \qquad (2)$$

There are two different methods of evaluating these sets of Equations: they can be integrated numerically or solved by series expansion. A derivative of the admittance of a load terminating a coaxial cable reported by (Mistra, 1987) was used with the following modifications:

$$Y_0 = \frac{2\pi}{\left[\sqrt{\frac{\mu_0}{\varepsilon_0 \varepsilon_c}} \ln\left(\frac{b}{a}\right)\right]} \qquad (3)$$

where Y_0 is the characteristic impedance, a and b are the inner radius and outer radius of the coaxial probe respectively, ε_c is the permittivity of the material filling the coaxial line. And the terminating load admittance is given as,

$$Y_L = j \frac{2\omega\varepsilon^*}{\left[\ln\left(\frac{b}{a}\right)\right]^2}\left[I_1 - \frac{k^2 I_3}{2}\right] + \frac{k^3 \pi \omega \varepsilon^*}{12}\left[\frac{b^2 - a^2}{\ln\left(\frac{b}{a}\right)}\right]^2 \qquad (4)$$

where

$$I_1 = \int_a^b \int_a^b \int_0^\pi \frac{\cos\phi'}{\sqrt{(\rho^2 + \rho'^2 - 2\rho\rho' \cos\phi')}} d\phi' d\rho' d\rho \qquad (5)$$

and

$$I_3 = \int_a^b \int_a^b \int_0^\pi \cos\phi' \left[\sqrt{(\rho^2 + \rho'^2 - 2\rho\rho' \cos\phi')}\right] d\phi' d\rho' d\rho \qquad (6)$$

The accuracy of the measuring system was improved by keeping the last term of Equation 4 close to zero. With these assumptions in place, Equation 4 therefore yields Equation 7 which was employed for nondestructive sensing of the dielectric properties of samples under test, that is

$$Y_L = j \frac{2\omega\varepsilon^*}{\left[\ln\left(\frac{b}{a}\right)\right]^2}\left[I_1 - \frac{k^2 I_3}{2}\right] \qquad (7)$$

Where the normalized terminating load admittance is related to the reflection coefficient by:

$$\widetilde{Y_L} = \left(\frac{1-\Gamma}{1+\Gamma}\right) \qquad (8)$$

3. Moisture content, oil content and electromagnetic interaction.

In this work, the moisture contents of the fruitlets were carefully measured using laboratory dry oven technique, this moisture content information was in turn used with Hartley relation to obtain the corresponding percentage oil content (Hartley, 1977). The computed dielectric constants for different moisture contents are plotted in Figure 1, while the oil content of the oil palm fruitlets at different values of loss factor are shown in Figure 2. Basically, the mesocarp of oil palm fruitlets is made up of three constituents; fiber, water and oil. The fiber is relatively constant once maturity is reached; the oil content of the fruitlets is therefore mainly dependent on the moisture content which is a function of the dielectric constant. The knowledge of this constituent ratio, together with the properties of microwave energy at 2-4GHz were employed in this work for effective and accurate grading of oil palm fruitlets based on the percentage oil contents.
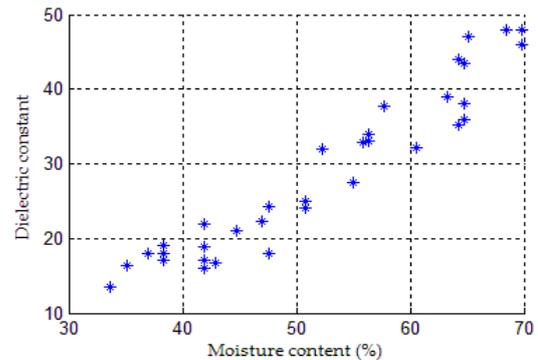
Figure 1 Measured moisture contents for different values of dielectric constant
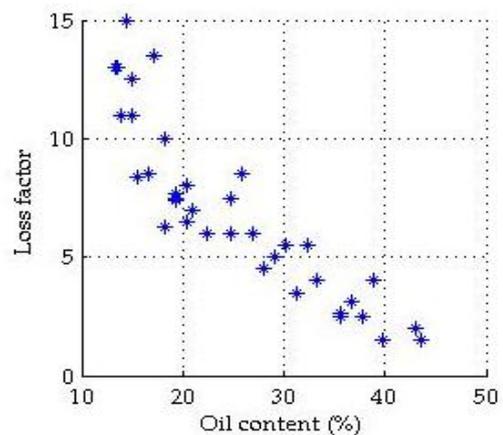
Figure 2 Measured oil content for different values of loss factor

It was observed as shown in Figure 3 that the dielectric constant of the oil palm fruitlet samples decreased with increasing oil content. Similar relationship was observed by (Trabelsi and Nelson, 2006) when the percentage moisture content was used to predict the bulk density of shelled peanuts.
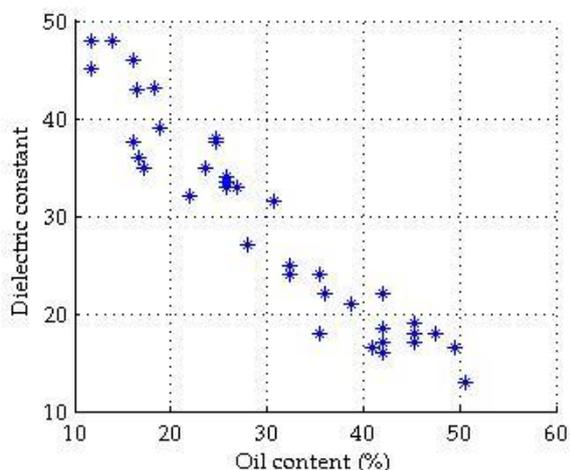
Figure 3 Measured oil contents for different values dielectric of dielectric constants

This relationship can be explained from the dielectric properties of water. Water has a relative permittivity as high as 80 at room temperature (Rhodes, 2013), therefore the presence of water in samples/materials has a significant effect on the response of such materials to electromagnetic (EM) energy due to high attenuation of the electric component of the EM waves. Even though the relative permeability of water is unity and therefore has insignificant effect on the magnetic component of the electromagnetic waves, the necessary energy cycling between the electric and magnetic component still makes attenuation of EM waves high in water (Castro-Giraldez *et al.*, 2010). This property which accounts for varying values of the complex permittivity of the oil palm fruitlets at different moisture/oil contents has also been highlighted by (Trabelsi & Nelson, 2006).

4. Graphical User Interface development

The Graphical User Interface (GUI) was developed using MATLAB Graphical User Interface Development Environment (GUIDE). This was done ensuring strict adherence to the elements for best practices for the design and architecture of Graphical User Interface which include performance, security, usability, localization and internationalization, reliability, scalability, supportability, and integrity. The interface was designed to have two major subpanels (see Figure 5); the microwave coaxial sensor measurement subpanel which computes the dielectric properties of the fruitlet under test, and the Layer Sensitivity-Based ANN (LSB_ANN) subpanel which predicts the percentage oil content of the fruitlet. The microwave

sensor subpanel was designed to take the inner and outer radius of the coaxial sensor, the permittivity of the filling material of the sensor, the measured reflection coefficient in rectangular form and the measurement frequency as user supplied inputs. It passes these parameters over to the GUI core. The GUI core contains the written M-file of the optimization of normalized conductance and susceptance and returns the computed dielectric constant as output.

Similarly, based on the user-supplied inputs, the Layer Sensitivity Based ANN (LSB_ANN) section predicts the fruitlet qualities as excellent, very good, fair or poor using the percentage oil content. This is achieved by passing the user-supplied phase and magnitude of the measured reflection coefficient into the trained LSB_ANN which in turn returns the desired outputs.

The "Calculate" execution button in the sensor parameter subpanel of the GUI is linked to the GUI core. When the button is clicked, the GUI core searches and obtains the values of the user supplied variables from the "Inner radius" input field, the "Outer radius" field, "Epsilon_c" field, "Frequency" field, the "Reflection coefficient" field and the "Initial value" field. These values are then passed to the .MAT file for the improved quasi-static dielectric model. This file returns the complex permittivity of the fruitlets under the user supplied conditions and sensor specifications to the GUI core.
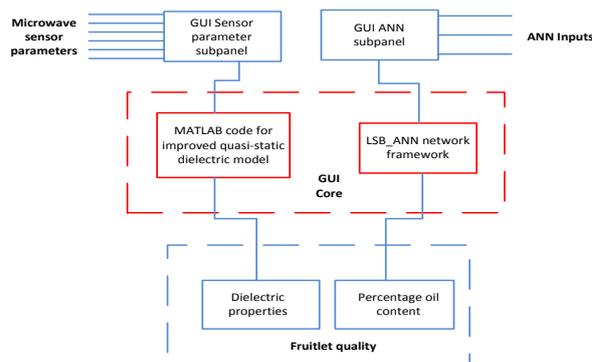
Figure 4 The GUI development stages and sub-units

The core then obtains the real part of the complex permittivity and this value is presented to the "Dielectric properties" subpanel as the dielectric constant.

The execution button "Characterize" is linked to the .MAT file that contains the pre-trained LSB_ANN. When the three ANN inputs are supplied by a user and the execution button "Characterize" is clicked, it passes control to the GUI core to obtain the inputs from the ANN subpanel. These inputs are forwarded to the LSB_ANN in appropriate order. The LSB_ANN then activates the MATLAB "simulate" command with the provided inputs as the associated parameters of the "simulate" command. The result of the simulation (in 3×1 matrix format) is then presented to the GUI core which in turn forwards it to the "ANN outputs" subpanel.
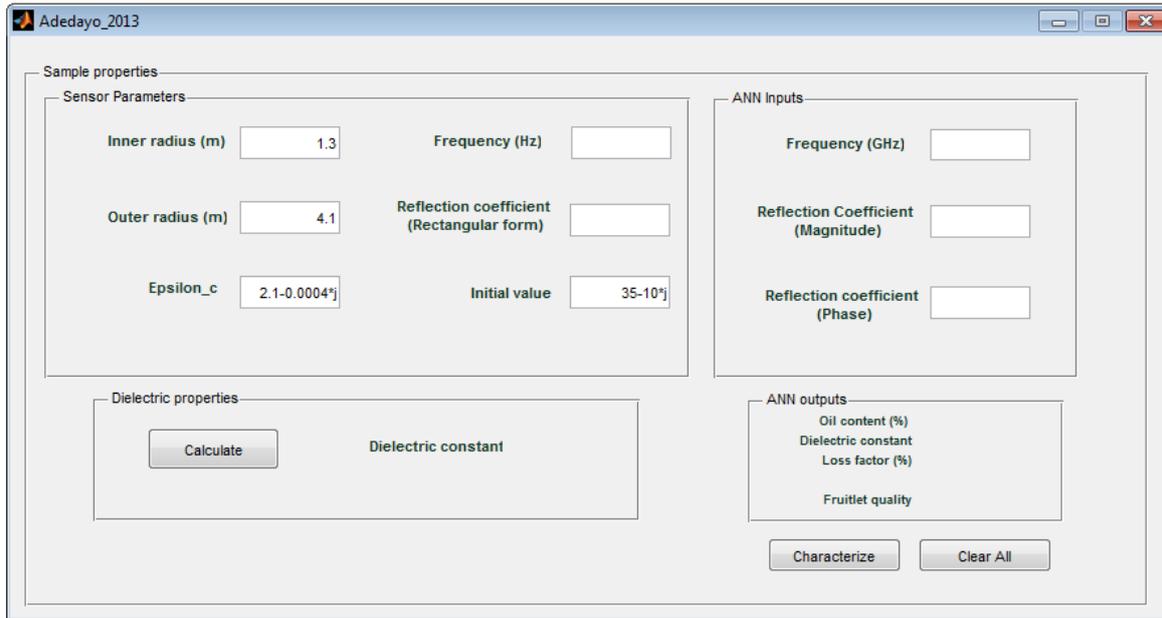
Figure 5 The GUI for intelligent characterization of oil palm fruitlets

The ANN output subpanel has the responsibility of obtaining the simulation results from the GUI core and interpreting the results in a human friendly language for users. After receiving the simulation results, the ANN output presents the overall quality of the oil palm fruitlet under test as excellent, very good, fair, or poor. This grading is based on the value of the LSB_ANN percentage oil content output which the ANN output receives from the GUI core.

When the "Clear all" button is clicked, it passes control to the GUI core to re-initialize all networks and programs within the graphical interface. This re-initialization forces the GUI core to clear all input fields in the sensor parameter subpanel as well as the ANN inputs subpanel. This enables users to enter new inputs and it saves time as the fields in the subpanels do not need to be cleared one after the other.

The Graphical User Interface was compiled in MATLAB and tested with data to confirm that its output in response to the supplied inputs corresponds with the trained stand-alone LSB_ANN network. With this Graphical User Interface (GUI) developed and linked to the trained LSB_ANN, the interface is suitable for obtaining the moisture contents, oil content and dielectric constants of oil palm fruitlets when the frequency and reflection coefficients are supplied (Figure 4.5). It also contains a section for obtaining the dielectric constants of the fruitlets from the first principle quasi-static solution described in this Chapter. If similar data collection and LSB_ANN design are carefully carried out, a similar GUI can also be designed and employed in determining the dielectric properties of other non-liquid organic substances through similar techniques employed in this work. The soft computing network approach to this problem has the unique advantage of good speed, low consumption of computing resources and re-trainability.

Conclusion

A means of accurately and rapidly extracting the dielectric properties and percentage oil content of oil palm fruitlet mesocarp for any ratio of coaxial cable sensor conductors was devised in this work using a layer sensitivity-based ANN. The network considerers both the magnitude and the phase of the measured microwave reflection coefficient together with the operating frequency and predicts the quality of the fruitlets. This approach eliminates the repeated use of laborious dry oven method for the extraction of moisture and oil content information. The performance of the LSB_ANN when supplied with a new set of testing data was evaluated using multiple evaluation criteria. The findings of this work show that conventional dielectric sensing methods are not suited for accurate oil palm characterization due to its heterogeneous nature, and that updating layer weights using sensitivity analysis improves neural network learning speed significantly. Also, it was shown that the need for use of computationally intensive admittance equation methods can be avoided by implementing a well-trained layer sensitivity based neural network. This represents a ready tool for accurately characterizing oil palm fruitlets for research purposes as well as *insitu* measurements using information obtained from the dielectric properties and oil content.

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