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Magnetic Induction Tomography: A Review on the Potential Application in Agricultural Industry of Malaysia

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Abstract

Agriculture is the foundation of Malaysia's economy in addition to other government-focused industries. The trend of its contribution to the gross domestic product (GDP) has fluctuated from year to year. The highest value was 28.8% in 1970; this reduced to 7.5% in 2007, rose slightly to 7.7% in 2009, and then decreased to 7.3% in 2010. However, the value is still high compared with other developed countries, the value of which is typically only within the range of 1% to 3%. This fluctuating trend is related to several factors both globally and locally, such as disease and diminishing resources. Despite the constraints and challenges faced by the agricultural industry, the quality of the produce has to be maintained, while solutions to the current problems are sought. Thus, this article discusses the possibility of using the technique of Magnetic Induction Tomography (MIT) in the agricultural industry for application in a fruit-grading system, the early detection of basal stem rot disease in palm oil trees, and resin identification inside a karas (*gaharu*) tree.

Keywords: agricultural, magnetic induction tomography, fruit grading system, basal stem disease, karas tree

1. Introduction

Agricultural industries have become fundamental to the economic growth of developing countries in the world, including Malaysia and her neighboring South East Asian countries of Thailand, Indonesia, Laos, Vietnam, Cambodia, The Philippines, Myanmar, and East Timorwith the exclusion of Singapore and Brunei.For Malaysia, even though agriculture is the foundation of the economy, the trend of its contribution to gross domestic product (GDP) fluctuates from year to year. Statistics have shown that the highest recorded value was in 1970 at 28.8%. This then decreased to 7.5% in 2007, rose slightly to 7.7% in 2009, and then dropped again to 7.3% in 2010 (Malaysia, 2010). This trend might be due to both global issues (global market price) and local factors (diseases, reduction of resources and government policy). Despite the challenges and apart from the actual quantity, a reduction in the quality of the agricultural produce cannot be tolerated, because quality will ensure that the produce is competitive, especially when entering theglobal market stream.

This article focuses on the potential of Magnetic Induction Tomography (MIT) imaging modality in improving, upgrading, and solving the problems existing in this industry. The scope of thestudyisthe application on MIT to the Harumanis fruit-grading system, the early detection of basal stem rot disease in palm oil trees,and resin detection inside a karas (*gaharu*) tree. It is hoped that MIT, through its non-invasive and contact-less technique, will provide the opportunity for improving the quality of agricultural fruit produce, reduce losses in investment by providing accurate early detection data on basal stem rot disease in palm oil trees, and preserve the natural forest through implementation of a "scanned-before-cut" technique in the karas industry.

2. Magnetic Induction Tomography (MIT)

MIT is a relatively new modality in tomography research, which falls within the family of passive imaging,together with Electrical Impedance Tomography (EIT), Electrical Capacitance Tomography (ECT), and Magnetostatic Permeability Tomography (MPT) (Soleimani, 2008). MIT, which has been applied in both industrial processes and the medical field, is a contact-less technique for reconstructing an image of the distribution of the passive electrical properties (PEPs) of a material: conductivity (σ), permeability (μ), and permittivity (ε). However, in most cases, conductivity has been the preferred choiceofresearchers,especially in the field of imaging biological tissue, because this property is dominant compared withthe other two (Z. Zakaria et al., 2012). In addition to it being ionizing-radiation-free, the use of electrode-less techniques means thatthis soft-field modality also avoids object-electrode boundary contacts, which have become major problems in EIT and ECT.

The MIT system comprises three parts: the sensor array (excitation coils and receiving coils), the conditioning electronics, and the image reconstruction algorithm, as shown in Figure 1. Excitation coils function as a transmitter, which generates an alternating primary magnetic field, $\boldsymbol{B_p}$.

This primary field then propagates through the object of interest located within the region of interest (ROI). An eddy current is induced within the object owing to the PEPs of the object itself. This eddy current then produces its own field, known as the secondary magnetic field, $\boldsymbol{B_s}$ or the eddy current field. The $\boldsymbol{B_s}$ carries the information on the PEPs distribution of a material; hence, at the receiver, only $\boldsymbol{B_s}$ is of interest.The principle of MIT is shown in Figure 2. All physical phenomena that exist in this modality follow Maxwell's laws, which are:

$$\nabla \times \boldsymbol{E} = -j\omega\boldsymbol{B} \quad (1)$$

$$\nabla \times \boldsymbol{H} = (\sigma + j\omega\varepsilon)\boldsymbol{E} \quad (2)$$

$$\nabla \cdot \boldsymbol{D} = \rho \quad (3)$$

$$\nabla \cdot \boldsymbol{B} = 0 \quad (4)$$

$\boldsymbol{E}$ is the electric field [V m^{-1}], ω is the frequency [rad s^{-1}], $\boldsymbol{B}$ is the magnetic field density [Wb m^{-2}], $\boldsymbol{H}$ is the magnetic field [A m^{-1}], $\boldsymbol{D}$ is the electric displacement field [C m^{-2}], and ρ is the free electric charge density [C m^{-3}].

The data collected at the receiver then undergo signal conditioning for filtering and amplifying before moving to the final step, which is the image reconstruction algorithm. At this stage, the image of the object of interest is reconstructed in either 2D or 3D.

3. Fruit Grading System

Current technology in fruit-grading systemsis normally based on the color of the skin of the fruits (Fadilah et al., 2012) and aroma (A. Zakaria et al., 2012). The most well-knowntechnique for detectingskin color is based on a CCD cameraand infra-red sensor with the implementation of an artificial neural network (ANN) for the ripeness algorithm classification.The limitation of this technique is that the ripeness of some fruitis not represented by the skin color. The skin color of the Harumanis mango, which is very popular in Malaysia, is always green, even when fully ripe (A. Zakaria et al., 2012), as shown in Figure 3; thus,the skin color technique is not appropriate for this species.

As a complement to this technique, the aroma-based technique can be implemented. In this scheme, an electronic nose is combined with an ultrasonic sensor to mimic the sensing technique used by fruit-eating bats, which use a combination of odor-guided detection together with echolocation to distinguish ripe fruit.In some cases, the odor does not reflect the taste of the fruit; there are cases of fruit, selected on odor and echo parameters, the taste of which is sour and not sweet as might be assumed. To increase the accuracy of the existing Harumanis grading system, MIT might play a role. Through the MIT imaging scheme, images of the internal structure of the fruit are reconstructed, where intensity of color represents the stage of ripeness. In addition, this system is also non-invasivelysensitive to the pH value of the fruit.

4. Basal Stem Rot Disease in Palm Oil Trees

Basal stem rot (BSR) is a major disease affecting Malaysian palm oil plants that is caused by *Ganodermaboninense*. The disease ultimately results in the destruction of the basal tissues of these plants and could kill up to 80% of the stand by the time the palms are halfway through their normal economic life span (Mustapha, Mazliham, & Boursier, 2011). An example of an affected basal stem is shown in Figure 4.

Existing BSR detection techniques are complex, time-consuming, and still not fully developed. Several researchers implemented x-ray fluorescence (XRF) techniques;however, the effects of the radiation have been the limitation in this method (Khalid & Seman, 2009). The University of Malaysia, Perlis, introduced an electronic nose (e-nose) detection scheme with the aim of insitu measurement (Abdullah et al., 2012). Despite its mobility and advantages of low cost, the weaknesses of the method are the accuracy of the results, because it is dependent on wind flow. Additionally, the odor from other affected trees mightinfluence the measurement results. However, even if the result is accurate, the e-nose is incapable of producing internal details,such as a cross-sectional image of the infected area. From theperspective of MIT, the internal region of the infected area can be obtained through a reconstructed cross-sectional image. From this information, treatment can be focused accuratelyon the infected region instead of on the whole stem, which might reduce the cost and time of the process.

5. Resin Identification in Karas *(Gaharu)* Tree

Karas or *Aquilaria* is a valuable aromatic tree, from which, at a certain age, resin exists inside the stem. There are many types of species of karas; however, the*AquilariaMalaccensis*species has the largest population in Malaysia's forest compared with the other species (Najib et al., 2010). This resin is traded worldwide in significant volumes, where the price is based on the resin content and type of resin itself. High-quality resin is priced at over US $3000 per kg and is used as incense, whereas the low-quality resin is used for the extraction of essential oil (Najib et al., 2012). A sample of the resin is shown in Figure 5.

There are several reported articles on the classification technique of the resin (Azah & Ali, 2012) once the karas tree has been cut; however, there has been little work reported on the non-invasive identification of the resin prior to the cutting process.A current and popular technique in South East Asia for obtaining the resin is normally by just cuttingthe trees. If the resin is present in large volumes, then the effort is worth it; however, if nothing is found, the tree is just abandoned. It is important to bear in mind that a karas tree takes up to 10 years or more to grow and produce matured resin in large volumes. Cutting down trees without an early identification of the resin quantity is a waste of resources. Thus, it is proposed that MIT could solve this issue. Based on the difference of passive electrical properties between resin and normal karas stem tissue, MIT has the potential to produce cross-sectional images of the internal structure of the stem, including the resin. Through this technique, only selected trees will be cut; hence, the karasresources could be preserved for future generations.

6. Conclusion

Magnetic induction tomography has great potential for application in the agricultural industry. There are many advantages of this modality, including being ionizing-radiation-free, robust, electrode-less and low cost. Based on its capability, we are confident that the implementation of MIT modality in agricultural will provide certain improvements in the monitoring of the quality of products, while at the same time preserving the natural forest.

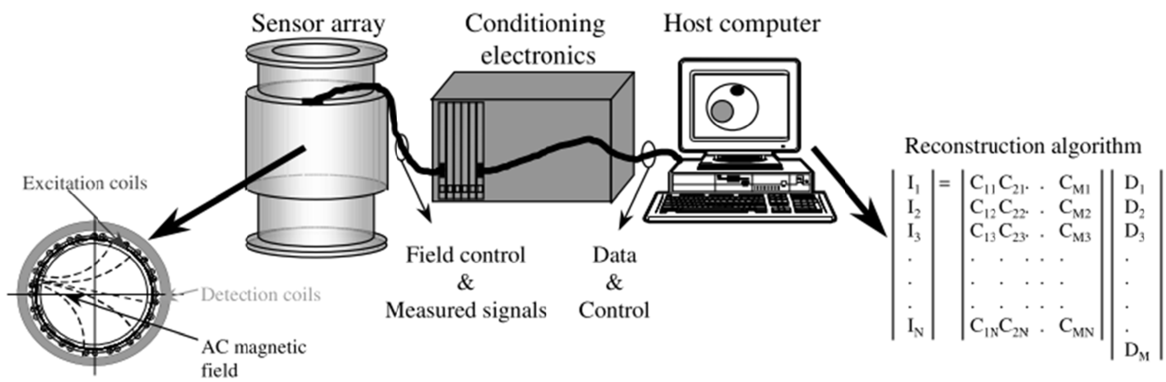

Figure 1. Components of an MIT system (Binns, Lyons, Peyton, & Pritchard, 2001)

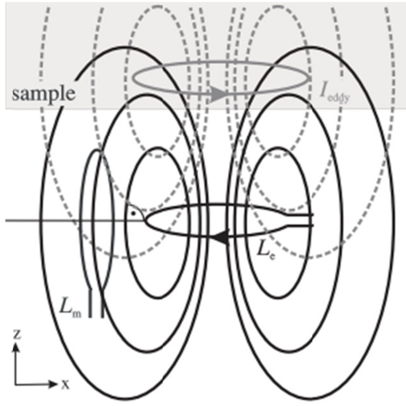

Figure 2. Principle of MIT modality (Igney et al., 2005)

Week 8 day 1 Week 8 day 7

Figure 3. Skin color of Harumanis mango at different stages of maturity (A. Zakaria et al., 2012)

Figure 4. Area of a palm oil stem affected by BSR disease

Figure 5. Sample of karas tree with resin

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References

Abdullah, A. H., Adom, A. H., Ahmad, M. N., Zakaria, A., Abd Ghani, S., Kamarudin, L. M., & Hamid, N. (2012). Exploring MIP Sensor of Basal Stem Rot (BSR) Disease in Palm Oil Plantation. *The 14th International Meeting on Chemical Sensors* (pp. 1348-1351). http://dx.doi.org/10.5162/IMCS2012/P2.1.7

Azah, N., & Ali, M. (2012). Analysis of Agarwood Oil (Aquilaria Malaccensis) Based on GC-MS Data. *2012 IEEE 8th International Colloquium on Signal Processing and its Applications* (pp. 470-473). http://dx.doi.org/10.1109/CSPA.2012.6194771

Binns, R., Lyons, A. R. A., Peyton, A. J., & Pritchard, W. D. N. (2001). Imaging molten steel flow profiles. *Measurement Science and Technology, 12*(8), 1132-1138. http://dx.doi.org/10.1088/0957-0233/12/8/320

Fadilah, N., Mohamad-Saleh, J., Abdul Halim, Z., Ibrahim, H., & Syed Ali, S. S. (2012). Intelligent color vision system for ripeness classification of oil palm fresh fruit bunch. *Sensors (Basel, Switzerland), 12*(10), 14179-95. http://dx.doi.org/10.3390/s121014179

Igney, C. H., Watson, S., Williams, R. J., Griffiths, H., & Dössel, O. (2005). Design and performance of a planar-array MIT system with normal sensor alignment. *Physiological Measurement, 26*(2), S263-78. http://dx.doi.org/10.1088/0967-3334/26/2/025

Khalid, M. A., & Seman, I. A. (2009). Identification Of Basal Stem Rot Disease In Local Palm Oil By Microfocus XRF. *Journal of Nuclear and Related Technologies, 6*(1), 282-287.

Malaysia, J. S. (2010). Selected Indicators for Agricultural, Crops and Livestock, Malaysia, 2006-2010. Retrieved from http://www.statistics.gov.my/portal/images/stories/files/LatestReleases/indicator/Summary_Indikator_Terpilih_Pertanian_Tanaman_dan_Ternakan2006-10.pdf

Mustapha, J. C., Mazliham, S., & Boursier, P. (2011). Temporal Analysis of Basal Stem Rot Disease in Oil Palm Plantations: An Analysis on Peat Soil. *International Journal of Engineering & Technology, 11*(3), 96-101.

Najib, M. S., Ahmad, M. U., Funk, P., & Taib, M. N. (2012). Agarwood Classification : A Case-based Reasoning Approach Based on E-nose. *2012 IEEE 8th International Colloquium on Signal Processing and its Applications* (pp. 120-126). http://dx.doi.org:10.1109/CSPA.2012.6194703

Najib, M. S., Mohd Ali, N. A., Mat Arip, M. N., Jalil, A. M., & Taib, M. N. (2010). Classification of Agarwood Region Using ANN. *2010 IEEE Control and System Graduate Research Colloquium* (pp. 7-13). http://dx.doi.org/10.1109/ICSGRC.2010.5562529

Soleimani, M. (2008). Computational Aspects of Low Frequency Electrical and Electromagnetic Tomography: A review Study. *International Journal of Numerical Analysis and Modelling, 5*(3), 407-440.

Zakaria, A., Md Shakaff, A. Y., Masnan, M. J., Ahmad Saad, F. S., Adom, A. H., Ahmad, M. N., & Jaafar, M. N. (2012). Improved maturity and ripeness classifications of Magnifera Indica cv. Harumanis mangoes through sensor fusion of an electronic nose and acoustic sensor. *Sensors (Basel, Switzerland), 12*(5), 6023-48. http://dx.doi.org/10.3390/s120506023

Zakaria, Z., Abdul Rahim, R., Mansor, M. S. B., Yaacob, S., Nor Ayob, N. M., Mohd Muji, S. Z., & Fazalul Rahiman, M. H. (2012). Advancements in Transmitters and Sensors for Biological Tissue Imaging in Magnetic Induction Tomography. *Sensors, 12*(6), 7126-7156. http://dx.doi.org/10.3390/s120607126