Abstract: The development of artificial olfactory systems, or electronic nose, for various applications has been on the rise due to their apparent benefits. The development and integration of electronic nose with other systems, such as mobile platform, increases its versatility and functionality. Proposed is a prototype of an electronic nose to be integrated with a mobile platform to perform as an automated malaise detection system in plantations. The electronic nose prototype were developed using off-the-shelf Figaro MOS sensors and Hitachi microcontroller, as well as rapid prototyping methods. Initial results show that the electronic nose is able to achieve 100% accuracy.

Keywords: electronic nose, neural networks, ganoderma.

1. INTRODUCTION

The development of artificial sensory systems such as electronic nose has been on the rise in recent years. The research into this area has been driven by the variety of applications of such systems and its advantages over conventional practices. For example, an electronic nose can be used to detect the presence of substances that are odourless, hence invisible to humans [1]. They may also be used to detect the presence of harmful or toxic volatiles. In addition to that, electronic noses are not susceptible to fatigue and more consistent compared to human counterpart [2] – [7].

Another obvious advantage of such system is the speed at which they learn to recognise odours. Unlike human experts that may take years to recognise certain discriminating characteristics of certain odours, like differentiating fruit ripeness, electronic nose can learn virtually in an instant. Artificial intelligence-based recognition algorithms, such as neural networks, provide a wonderful tool to allow electronic nose to be able to recognise or discriminate odours rapidly [8] – [10].

To further increase the versatility of electronic noses, they can be integrated with other systems, such as autonomous mobile platforms to enable automated detection of odours for many applications. As an example, the agricultural industry can benefit tremendously from the development of an automated plant malaise detection system to be used in estates and plantations. Such a system may be used for many applications such as early detection of diseases before the damage to the plants has been done. Moreover, generic detection systems that could be appropriately tuned to detect a variety of diseases that may affect different types of plants are best.

The development of such systems may be made faster by using commercially available electronic noses. However, these are very costly and some do not offer advanced pattern recognition algorithms. Initial investigations using Cyranose indicates that the system may benefit from the use of artificial intelligence for its classification algorithm over the use of embedded tools made available.

This paper presents the development of an electronic olfactory prototype of an automated malaise detection system for the agricultural industry using off-the-shelf sensors and microcontroller. The electronic nose is to be used as a rapid early detection system and forms a part of an automated plant malaise detection system in the estates. The Basal Stem Rot (BSR) disease that is a threat to the oil palm industry was chosen as a model in an application to the newly developed system.

2. OIL PALM TREES AND BASAL STEM ROT DISEASE

The oil palm (Elaeis guineensis Jacq.) tree is a leading source of edible vegetable oil production in the world, with production figures of more than 32 million tones of oil in 2003. In Malaysia, the hierarchy of palm oil as a leading cash crop has exceeded that of natural rubber, and its importance has been further boosted by the recent introduction of bio-diesel.

Its cultivation, in much of South-East Asia, is threatened by the BSR caused by Ganoderma boninense,
where losses can reach as much as 80% after repeated planting cycles. BSR has been causing serious damage to the oil palm plantations in Malaysia for more than 50 years [11] and is currently the most important disease of economical importance causing large amount of losses in revenue. Under severe infestation situations, more than 50% of oil palm stand can be lost to the malady. The FELDA plantations, for example, recorded high incidence of the disease in the Peninsular Malaysia, ranging to about 50%, from 1994 to 2005. The disease does not show indication of early infection whereby it progresses through the palm from the base without any observable symptoms, leading to eventual death of the palm. It causes root and stem rots in many tropical perennial crops, including coconut, betel palm, rubber, tea, coffee, cocoa and forest trees [12].

It has been demonstrated that Ganoderma sp. can set in as early as 12 to 24 months after planting but more usually when the oil palm is 4 to 5 years old, particularly in replanted areas [13]. The incidence increases rapidly to the extent that by the time the palms were 15 years old, the disease levels can reach between 40 to 50 per cent of the palm. In severe cases, up to 85 per cent of the standing palms succumb to BSR by the time the palms are 25 years old.

It is estimated that if only 2.5% of the total acreage of the oil palm plantation in Malaysia is affected by BSR, the industry would lose about RM80 million each year. This amount could be turned into profit if there exist an early detection system in the form electronic nose for the Ganoderma sp.

3. ELECTRONIC NOSE PROTOTYPE DEVELOPMENT

The development and fabrication of the electronic nose were completed in several stages. The first involved the design and fabrication of the internal modules of the electronic nose, which includes the odour capturing module, the microcontrollers as well as the signal conditioning circuits and voltage regulators for the sensors.

The electronic nose consisted of a tunnel lined with a series of metal-oxide sensors. A fan, which acts as a suction module, is placed at the end of the tunnel. When the fan is switched on, air stream would be dragged in and thus, allowing the airflow to percolate the sensors.

4. METHODOLOGY

Once the electronic nose has been fabricated, only then can the data collection, network training and system testing can be carried out. This is because the setup of the system used for the testing must be exactly the same at the setup used for data collection prior to the network training. Otherwise, the data recorded during data collection for network training and system testing will not be identical. Hence their comparison will not be valid.

4.1 Data Collection

Data of sample readings of healthy and infected palm oil trunks were used for the training for the electronic nose. The readings taken were of the odour of the trunk of the palm oil tree. The tree trunks were bored and the sample collected, and the odour were recorded on-site. The samples of the bored tree trunk were also collected and taken to the laboratory for the electronic nose testing. Odours from both healthy and infected trees were recorded.

The readings from the sensors were sent to the onboard microcontroller and stored in the EPROM, and were then sent to the PC via a serial connection. All of the collected data from the sensors were scaled to avoid any dominance of any sensors. This is because the sensors do not have a standardised output range, and those with larger output magnitude would affect the system’s output.

4.2 Network Network Training

The data was trained using the basic MultiLayer Perceptron (MLP) neural networks with Backpropagation algorithm in MATLAB. The training data consisted of 300 data pairs, with 150 representing healthy tree and the other 150 representing infected tree. Neural network with eight inputs and hidden nodes were used.

The scaling factors for all of the sensors were recorded to be used again when the system is in operation. Upon completion of the network training, the electronic nose, dubbed as GanoBuster, was able to recognise the chemical signature, hence the presence, of Ganoderma sp.

4.3 Electronic Nose Testing

Once the training has been conducted, the neural network code was translated into C programming language and downloaded onto the microcontroller of the unit. The next stage was the testing phase, where the system was tested on new samples of healthy and infected palm oil trunks. The testing uses random samples of both infected and healthy oil palm samples.
The testing was conducted in three stages. Stage 1 tested only the samples of the healthy bored tree trunk. Stage 2 tested the infected samples, and stage 3 uses a mix of the infected and healthy tree trunk samples.

5. RESULTS AND DISCUSSIONS

The training and testing of the electronic nose showed that it was able to discriminate healthy and infected tree trunk samples.

Figures 3 and 4 show the result of the training of the neural network. Figure 3 shows the output of the electronic nose against the set target, i.e. output of zero for healthy sample, and an output of 1 for infected samples.

![Figure 3. The testing of the electronic nose at the end of the training.](image)

The network was also tested continually during the testing to validate the learning process. At the end of every epoch, the weights were frozen and the network tested using a different set of data. The result is shown in Figure 4.

![Figure 4. The plot of the SSE of the testing conducted at the end of every epoch during network training.](image)

After the completion of the network training phase, the electronic nose are again tested using a total of 400 data samples in three stages, and the results are as shown in Table 1. This test using new samples of healthy and infected palm oil tree trunks showed 100% accuracy.

<table>
<thead>
<tr>
<th>No</th>
<th>Sample</th>
<th>Sample size</th>
<th>Accuracy %</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Healthy</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Infected</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Healthy and infected</td>
<td>200</td>
<td>100</td>
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6. CONCLUSIONS

The development of the electronic nose has proven to be successful by using off-the-shelf sensors and microcontroller. This truly provides feasible alternative to the commercially available electronic noses which are very costly.

However, the Hitachi microcontroller adopted for this prototype has memory limitations to allow on-line learning as well as more elaborate algorithms to be implemented. Another microcontroller, Rabbit RCM4000 will be used in the next prototype currently being developed.

7. FURTHER WORK

The electronic nose will be part of an automated plant malaise detection system being developed by the group. The system will scout the estates and will sample the soil for the detection of Ganoderma sp. However, it is also can be used manually in the field using separate power supplies. The operator needs to heat the sensors for about three minutes and collect the odour sample. The classification or detection is then instantaneous.

The electronic nose system developed can easily be adapted to detect other plant malaise by just retraining the neural network of the system. The retraining will need data collection of healthy and infected samples, and downloading of the neural network onto the microcontroller. The whole process can be conducted in a matter of days.

Another great advantage of the electronic nose is that it can actually be trained to detect or discriminate other parameters. For example, the odour of ripening fruits can be used to accurately classify the ripeness levels of fruits. This is advantageous in that it can replace the use of experts, especially for fruits that do not exhibit physical changes as they ripen.

At the moment, the group is also working on automated system learning, whereby the training of the neural network of the system conducted by the system’s microprocessor without the need of MATLAB or other simulation softwares. The system will be part of a human mimicking sensory system. The electronic nose will be combined with an artificial tongue also developed by the research group.

8. REFERENCES


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