Institution: King's College London (KCL)

Unit of Assessment: B11: Computer Science and Informatics

Title of case study: Portable Electronic Red Palm Weevil (Rynchophorus Ferrugineus Olivier) Larvae Detector [RWL]

1. Summary of the impact (indicative maximum 100 words)

Research led by Dr Nanayakkara has directly enabled the development of a new sensing device that offers 97% accuracy in the discovery of red weevil palm infestations, allowing early treatment and significant financial savings for coconut producers. An estimated 10% of the global palm production is damaged due to a pest called the red palm weevil. In Sri Lanka alone, contributing approximately 2% of the World's coconut production, the annual cost of the damage is estimated to be around £15 million, causing both economic and social problems. Dr Nanayakkara, in collaboration with the Sri Lanka agricultural council, has developed a portable electronic device that has been demonstrated to be 97% accurate in field trials conducted by the Coconut Research Institute (CRI) of Sri Lanka. The CRI has recommended this device to more than 5000 coconut state owners in Sri Lanka as the best available red palm weevil detector.

2. Underpinning research (indicative maximum 500 words)

The underpinning research includes novel signal processing techniques and, as the process of development progressed, research into energy efficiency, materials, ergonomics and sensor design. Signal processing research has concentrated on the role of larval motor primitives in action generation and the temporal and frequency characteristics of acoustic signals generated by the crunching behaviour of red weevil larvae (RWL). Use is made of appropriate signal processing algorithms to extract signals that can be used to cue human recognition of the auditory signals that reveal infestation.

Role of motor primitives on action generation: In [1] it is shown that motor primitives have correlated tuning in position and velocity spaces, leading to characteristic signal generation. The motor activity of RWL is governed by a few ganglion circuits that work as central pattern generators, so it follows that a series of characteristic frequency bands in the acoustic signal can be anticipated from the crunching behaviour of RWL. The signal processing algorithm developed by Nanayakkara and his collaborators is optimized to preserve the characteristic features of the rhythmic crunching behavior of RWL, while filtering out the noise generated by the twist of the trunk and sway of leaves due to wind, activity of other insects, movement of water in the tree trunk, and other background sounds.

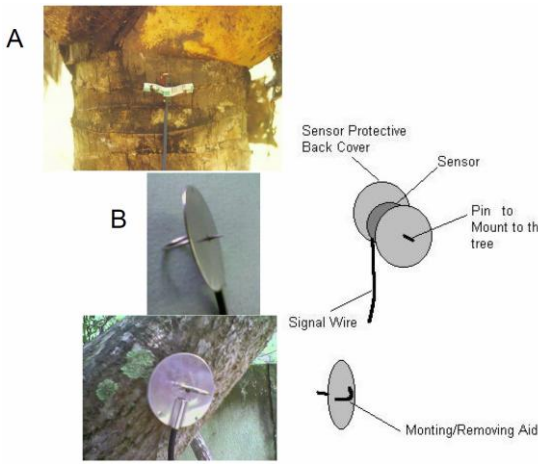

Figure 1: The novel sensor head designed to serve the needs of quality sensing and ergonomics of field handling.

Novel transducer arrangement: Extensive field experiments over six years helped in determining that fast checking from four different places on the trunk of the tree improves the accuracy in localizing the infested region of a tree [2]. The precision of sensor placement, by punching a pin attached to the transducer into the hard bark of the tree, was found to play an important role in this regard. After studying

human ergonomics, a sensor arrangement was designed that makes it easy for a user to mount the sensor on a relatively stiff coconut tree trunk using the thumb and pull it out using the index finger as shown in Figure 1 (A) and (B). The exact dimensions of this arrangement are being patented. Worse-case scenarios of applied forces were studied to design the material and strength of the complete sensor arrangement.

Exploitation of the role of short term memory in human auditory signal discrimination: The background sounds mentioned above make it difficult to detect the weak acoustic signal generated by the RWL using the conventional practice of placing the ear on the trunk of the tree. Field experiments supported the discovery that the signal discrimination capability of the human auditory system improves when participants try to detect the crunching activity of the RWL in coconut palm trees soon after listening to a refined auditory signal of the crunching sound of RWL. This led to inclusion, within the device, of a pre-recorded sound clip of the crunching sound to enhance the detection accuracy [3].

Key Researcher at KCL

Dr. Thrishantha Nanayakkara
King's College London throughout REF period

3. References to the research (indicative maximum of six references)

***[1]** G. Chin-Wei Sing, W. M. Joiner, T. Nanayakkara, J. B. Brayanov, and M. Smith, "*Primitives for motor adaptation reflect correlated neural turning to position and velocity*", Neuron, vol. 64, Issue 4, pp. 575-589, November 2009. DOI: 10.1016/j.neuron.2009.10.001
***[2]** K.A.P. Siriwardena, L.C.P. Fernando, N. Nanayakkara, K. F. G. Perera, A.D.N.T. Kumara and T. Nanayakkara, "*Portable Acoustic Device for Detection of Coconut Palms infested by Rynchophorus ferrugineus (Coleoptera: Curculionidae)*", Journal of Crop Protection, vol. 29, pp. 25-29, 2010 DOI: 10.1016/j.cropro.2009.09.002
***[3]** J.G. Taylor, V. Cutsuridis, M. Hartley, K. Althoefer, and T. Nanayakkara. "*Observational Learning: Basis, Experimental Results and Models, and Implications for Robotics.*" Cognitive Computation: September 2013, Volume 5, Issue 3, pp. 340-354 DOI: 10.1007/s12559-013-9208-1

Relevant Grants:

Departmental Pump-priming funds, 2012: £2000
Council for Agricultural Research Policy of Sri Lanaka (CARP) funding for embedded sensor design prototypes, 2005: £3253

* Publications indicating quality of underpinning research.

4. Details of the impact (indicative maximum 750 words)

Financial losses due to red weevil attacks are caused by two factors: direct loss of seedlings due to infestation, which includes the investment in nurture of the seedlings, estimated at approximately £10 million per annum in Sri Lanka alone, and the loss of production while replacement trees are established for those that are infected, taking five years to reach production maturity. The latter loss is estimated at £5 million per annum in Sri Lanka. Early detection of the red weevil can

significantly reduce the lost investment in seedlings and the loss of production, since early chemical treatment can kill the pests. Sri Lankan production amounts to about 2% of world production of palm nuts.

The Coconut Research Institute of Sri Lanka (CRI) has been investigating technologies suitable for detection of RWL for more than a decade. However, earlier devices had failed to achieve adequate levels of detection accuracy and suffered from high power demands and weight. For example, the Davis detector and a further Sri Lankan design, both require two 9V batteries for operation and were too bulky for convenient portage around plantations.The CRI approached Dr Nanayakkara to request his help in the development of a new device.

Dr. Nanayakara proposed going beyond acoustic signal processing to a hybrid approach combining embedded signal processing with the human auditory signal discrimination capacity, based on both neuroscientific research and the biological basis of the RWL crunching behaviour. The development of the device progressed from laboratory prototypes to a field trial version capable of deployment. The final design is deployed, currently in small numbers, although larger scale manufacture is in progress.

Figure 2: The novel detector being used in a field trial.

Weight reduction and compactness: By careful design for efficient energy management Nanayakkara and his team engineered a system powered by a single 9V battery. Their new technology not only saves power, but also reduces the total weight of the device. The current design (show in use in Figure 2) uses only 10 x 8 x 4 cm of space (a more than five-fold reduction in volume over the first prototype).

Higher accuracy of detection: Field-testing over the last two years has supported better understanding of the ideal way to use the device and the final device detects infested palms with an accuracy of 97% at the first observation, which can be further improved by re-checking one month later. It is also highly reliable (93%) in identifying true negatives (identifying unaffected trees). This field trial evidence has been critical in the progress from field trial to the recommendation for widespread use.

Design Success Recognition: In 2012, Dr Nanayakkara was shortlisted by the Royal Academy of Engineering for the ERA Foundation Entrepreneurs Award in recognition of the significance and design achievements in the construction of the detector [B].

Deployment: Once a quality assurance report was obtained from the Coconut Research Institute of Sri Lanka, 25 devices were manufactured and sold to farmers. It was found from the feedback from the farmers that in addition to the high reliability of detecting infested palms, the use of the device provides many advantages:

a. Detection of early stage of infestation, even when external symptoms are not visible.
b. No cleaning of palms is required before use, which saves the cost of labour compared to the checking of palms by the previously recommended method.
c. A very short time of about 1 - 3 min is required to check each palm.
d. The device can be used to check whether chemical treatment applied on palms is effective.
e. User-friendliness in mounting of the sensor on the palm and clear output of crunching sound make the device convenient and practical to use.

The farmers are overwhelmingly positive about the use of the device.

The Coconut Research Institute director confirms [A]: "*25 units have already been distributed among the farmers at cost and there is an overwhelming demand to produce more. We have commissioned an initial production run of 50 units while we tender for large scale manufacture of the device.*" and "*In recognition of Dr Thrishantha Nanayakkara's significant role in the R&D phase, the CRI has included him in the patent application that has been filed.*"

He also observes [A]: "*The Coconut Research Institute considers this Red Palm Weevil detector to be the best tool to aid coconut estate owners to detect the Red Weevil Larvae in palms at the early stage of infestation, allowing them to treat the pest as early as possible. We have therefore recommended it to the coconut estate owners in Sri Lanka."*

5. Sources to corroborate the impact (indicative maximum of 10 references)

The following documents corroborate the quoted elements above and their authors can corroborate claims for production numbers, deployment and use of the device, as well as the role of KCL research in the development of the detector.

[A] Letter of support and report on manufacturing orders from the Coconut Research Institute, Sri Lanka.

[B] Letter confirming shortlisting for Royal Academy of Engineering ERA Foundation Entrepreneurs Award, 2012.