Applications of optical spectroscopy and multispectral imaging in life sciences

A thesis submitted to the Faculty of Science,
University of Colombo
for the Degree of Doctor of Philosophy

H. H. E. Jayaweera
November 2014

Abstract

Realistic scalable optical spectroscopic and multispectral imaging instrumentation platforms as non-invasive optical diagnosis/detection systems have been developed and are presented in this thesis. Wherever possible the state-of-the art optical and electronic instrumentation techniques were employed in the development work, and the developed instruments have been used in specific applications related to medicine, ecology and agriculture. Several research and application tools have been designed and constructed under this project.
A detailed description is provided in the thesis with regard to the development and commissioning of a GAs in Scattering Media Absorption Spectroscopy (GASMAS) setup, which is the first of its kind built in Sri Lanka. GASMAS was used as a non-destructive testing instrument for assessing the quality of the coating (an edible wax) which is sprayed for preserving the freshness of paprika. For a good quality coating it has been found that, the time constant for outward Oxygen diffusion of paprika was 58±5 h (even after 14 days of shelf life). The main drawback of the GASMAS techniques is its inability to determine the absolute optical path length.

A novel technique to measure the absolute optical path length using frequency modulated continuous wave (FMCW) has been developed, which enables the estimation of path lengths with the maximum accuracy of 14.3 %.

Application of chemometrics for point spectroscopic non-invasive investigation of physiological maturity paprika using reflectance and florescence excited with the help of light emitting diodes (LEDs) has also been carried out. It was revealed that the system can estimate physiological maturity of different varieties of paprika up to 12 h.

In another development work, a web camera based diffused macroscopic red, green and blue (RGB) imaging system has been designed and constructed, and this system was successfully used to estimate the severity of cassava mosaic virus infestation, and to classify selected Sri Lankan tomato varieties. The system was capable of discriminating senescence leaf from severely infected cassava leaf. The imaging system was also found to be capable of sorting Sri Lankan tomato varieties of Maheshi, Rajitha, T245 and Thilina with sensitivities of 93 %, 87 %, 42 % and 44 % respectively, and with specificities of 88 %, 90 %, 40 % and 38 % respectively for up to three days after the plucking the fruits.

As a related development study, an LED based multimode microscopic system, as a research tool, was also designed and constructed. The ability to analyze blood smears without staining is one of the main advantages of this system. It was found that the system was capable of discriminating oxyhemoglobin, deoxyhaemoglobin and *Plasmodium falciparum* parasites (Malaria Parasites) in red blood cells.

A novel passive remote sensing technique was developed for bio aerosol (insect) monitoring. As a related study, habitat of *Calopteryx splendens* and *Calopteryx virgo* were monitored with the system. A total of 1,285 insect events passing the field of view were recorded in situ with the system in a period of 12 h. Based on the analysis of these events it was possible to differentiate male and female types of the insect of both varieties separately. The system also successfully detected the interactions within and between sexes of the same species pertaining to territorial behaviours and chasing of potential mates.