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A Noninvasive Approach for Diagnosis of Human and Plant Diseases: Near-Infrared Spectroscopy

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ABSTRACT

Non-destructive screening of human or plant organs is necessary to diagnose the disease for its real-time and to-the-point treatment. Along with numerous other remotely sensed approaches, near-infrared spectroscopy (NIRS) has continued to facilitate the scientific community for disease diagnosis. The NIRS is being applied in numerous fields for diverse kinds of quality, quantity, and estimation studies. This mini-review focuses on some of the human and plant-related disease studies using the NIRS.

Introduction

Near-infrared spectroscopy (NIRS) lies in between visible and infrared spectroscopy and bears characteristics of both electronic and vibrational spectroscopy ranging from wavelength 800-2500 nm. After the start of the systematic measurement of the NIRS in the 1920s [1], it got attention in the 1950s for investigation on anharmonicity [2], and in the 1960s an agricultural engineer (Karl Norris) explored the potential of NIRS for quality assessment of the agricultural products [3]. Since the 1980s, NIRS has been adopted as a precise and reliable approach for non-destructive studies of objects. After the development of computers, detectors, spectrometers and chemometrics. NIRS has been adopted by several industries (environmental analysis, biomedical sciences, agricultural sciences, cultural resources, petroleum, chemical, pharmaceutical and polymer industries). Moreover, NIR spectroscopy is growing substantially for brain science, paleocultural property science, forensic science, building site, safety sensing, astronomy, and security [4-6]. NIR spectrometers are comprised of a detector, spectrometer, and optical system for sample and light source (Figure 1). These are configured in two ways (Figure 1a & Figure 1b). (Figure 1a). the sample is placed after the spectrometer and irradiated by monochromatic light (Figure 1b). the sample is irradiated with the light source and placed after it. The NIR light sources are different like Thermal radiation, light-emitting diode, laser diode, supercontinuum light, and solid-state laser [7].

The use of these spectrometers to acquire data results in a huge bunch of datasets with redundant information relevant to the target problem because of the continuous number of light energy bands. Therefore, different feature selection and extraction approaches are adopted to diagnose the disease [8,9]. Numerous, machine learning techniques are used to extract sensitive information [10]. Herein, we will discuss the application of the NIR spectroscopy (hyperspectral images) for the investigation of human and plant.

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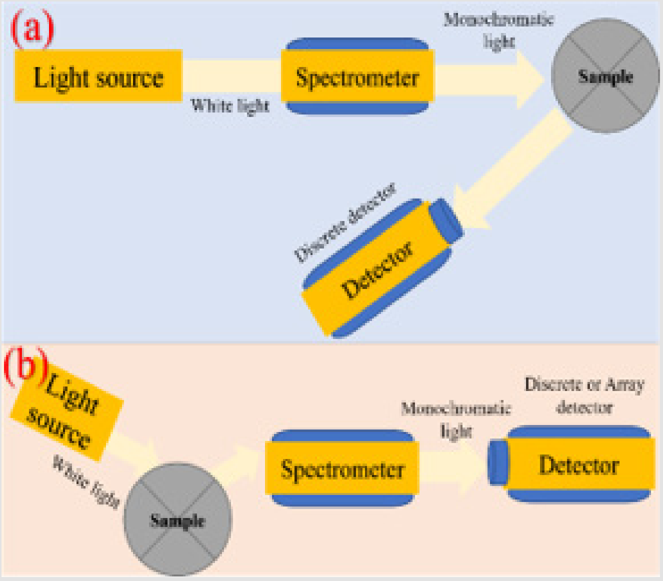

Figure 1: Configuration of NIR spectrometers.

NIRS for Human Diseases

NIRS has been used for disease diagnosis and image-based surgeries. The spectral characteristics of the NIR images provide the real-time biomarkers of deoxyhemoglobin and oxyhemoglobin [11]. NIRS has magnificent potential for disease quantification, estimation, diagnosis, screening, and detection because it can detect the [12-14]. Previously, numerous studies have employed NIRS for the examination of human diseases. Cancer disease has been studied comprehensively using NIRS for different organs of the body i.e. tongue [15], brain [16], skin [17], breast [18], colon [19], cervix [20], urothelium [21] and many other organs. The study detected enlarged angiogenesis which causes cancer [22]. The cervical epithelium was classified using fluorescence and reflectance spectroscopy [12]. In another finding, (Siddiqi, et al. [23]) successfully made the Pap test on cervical cells using hyperspectral images. (Wood, et al. [24]) used NIRS for squamous and glandular epithelium. (Hattery, et al. [25]) identified the blood volume with six thermal NIRS bands. The results indicated that spectral signatures of blood volume can be used to indicate tumour metabolism and tumour angiogenesis. The hyperspectral images of pathological slides ensured the detection of the head and neck cancer metastasis [26] and spectral data of the tongue was acquired non-destructively to examine the disease [15].

(Masood, et al. [27]) explored the NIRS images to classify the malignant and normal biopsy tissues, examining the geometrical, orientation, size, and shape traits of the cellular components. Similarly, a detailed study was conducted for colon cancer in which two modalities (hyperspectral images and fluorescence) of NIRS were fused to detect labeled antibodies. It was examined by mouse model in xenograft tissue in well precise manner, time, and cost-effectively [28]. Regarding circulatory and heart disease studies, fluorescence and reflectance spectroscopy was applied to diagnose atherosclerosis as fibrous plaque [29]. (Johnson, et al. [30]) diagnosed the human retina using hyperspectral images. (Yudovsky, et al. [31]) comprehensively reviewed that how NIRS can be employed for Diabetic foot. In nutshell, a numerous studies have employed and verified the NIRS for various human diseases.

NIRS for Plant Diseases

The plants' disease severely affects the biochemical properties of the plant leaves or any infected part. Therefore, multiple studies have considered and employed the NIRS for plant studies. Hyperspectral images are the most important ones which are vastly applied for plant disease. The reflectance pattern gets changed as shown in (Figure 2). Hyperspectral images have its roots in national aeronautics and space administration's Jet Propulsion Laboratory with the development of the Airborne Imaging Spectrometer in the early 1980s [32]. HSI technology combines the science of spectroscopy with imaging to acquire both spectral and spatial information of an object or scene simultaneously [33]. Whereas, a push-broom type scanner has been used to inspect individual grapefruits for citrus canker [34] and in wheat for yellow rust disease [35]. A pixel-wise mapping of spectral reflectance in the NIRS range enabled the detection and detailed description of diseased tissue at the leaf level [36]. However, a pixel-wise attribution of disease-specific symptoms and healthy tissue is conducive for observing spectral reflectance patterns of foliar diseases in detail. Some disease symptoms can only be distinguished from other diseases and stresses when NIRS with a high spatial resolution is used [37]. Therefore, feature extraction methods have been widely developed for monitoring several plant conditions.

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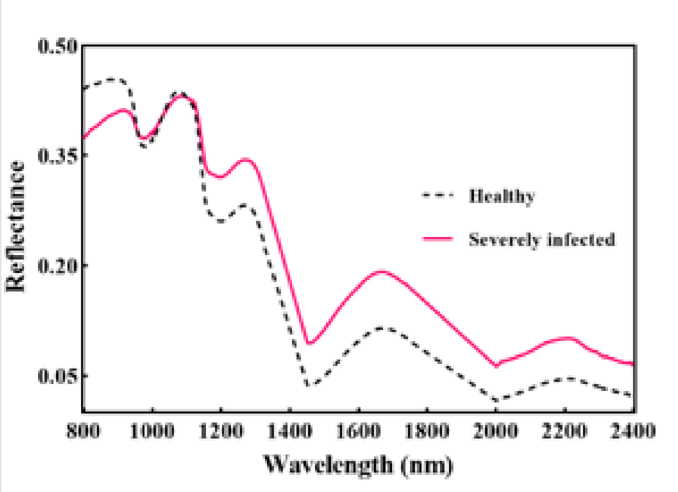

Figure 2: Canopy reflectance pattern in NIR range.

Different attributes such as physical and morphological plant characteristics have been used for feature extraction which is obtained by NIRS. (Zhang, et al. [38]) demonstrated an application for leaf disease detection in cucumber plants. Initially, the application isolated the infected part of the leaf through k-means clustering while color and shape are extracted reaching an accuracy of 85.7%. Similarly, (Guo, et al. [39]) utilized texture and color features using a Bayesian approach for recognizing downy mildew, anthracnose, powdery, and gray mold infection with respective accuracy rates of 94.0%, 86.7%, 88.8%, and 84.4%. However, (Vianna, et al. [40]) developed a neural network based pattern recognition approach for detecting the globally dominant tomato late blight disease.

Conclusion

A very disease-specific introduction and review of NIRS for plant and human diseases elucidate the successful application for diagnosis. The biochemical changes in the infected parts give detectable signals to the detector and make successful use of it. However, concise and comprehensive efforts still needed to be made for the large-scale use of this technology in the special context of the cost and availability for developing countries.

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