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A Portable Spectra Detection System for Ripeness Detection and Real-Finger Identification

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Abstract—A portable spectra detection system has been developed to enable reflection measurement. This system is mainly composed of spectrometer, LED source and five optical elements. The size of the optical system is about 126 mm × 72 mm × 30 mm. The system covers a range of 340 nm–820 nm, and the spectral resolution is 6.0 nm. Based on the detection system, two example applications for ripeness detection and real-finger identification are carried out to demonstrate the system performance. The detection time is less than 1 second, and a satisfactory agreement is observed between detection results and realistic situation.

1. INTRODUCTION

Optical spectroscopy has been a powerful analytical tool in research and industrial applications [1–5], such as pharmaceutical testing [1], assessing food [2, 3] quality and diagnostics [4, 5]. At present, in order to meet the needs of in-site spectrum detection, portable spectrometer has become a research hotspot [6]. However, there are still some difficulties in the development and application of portable spectrometers for many non-optical professionals. In this paper, a portable reflection spectral system is developed. Widely used spectrometers, LED source, optical components and electronic devices are used to compose the system. Majority of scientific researchers can build up their own portable spectral detection system based on the information of this paper. Using this system, we have realized the banana ripeness detection, as well as the function of real-finger identification. The detection time is 100 ms, and the structure of the system is compact, making it ideal for in-site spectrum detection.

2. PORTABLE SPECTRA DETECTION SYSTEM

Figure 1 shows the developed portable spectra detection system. In this study, the optomechanics elements are mainly from Thorlabs. The size of this system is about 126 mm × 72 mm × 30 mm. The spectra detection module is a commercial miniaturized spectrometer (STS, ocean optics), which is with the advantage of high stability, high spectral resolution (1.0 nm with 10 μm slit). However, the STS is a fiber based spectrometer. If the fiber is utilized in the system, the compactness of the system will be deteriorated. Also, Optical detection efficiency is reduced when using fiber to coupler spatial light. Meanwhile, Optical fiber needs careful maintenance, which is also a potential difficulty for non-optical professionals. In order to combine the spectrometer and other optical elements without a fiber, the SM1PL (with a homemade 1/4-36 threaded hole in the middle) is used. This way, the spectrometer and the SM1L10 (Thorlabs), can be connected together. SM1L10 is a lens tube, and holds a doublet lens(Lens-2 in Fig. 1(b)) and a polarizer. This doublet lens is utilized to enhance the spectral detection

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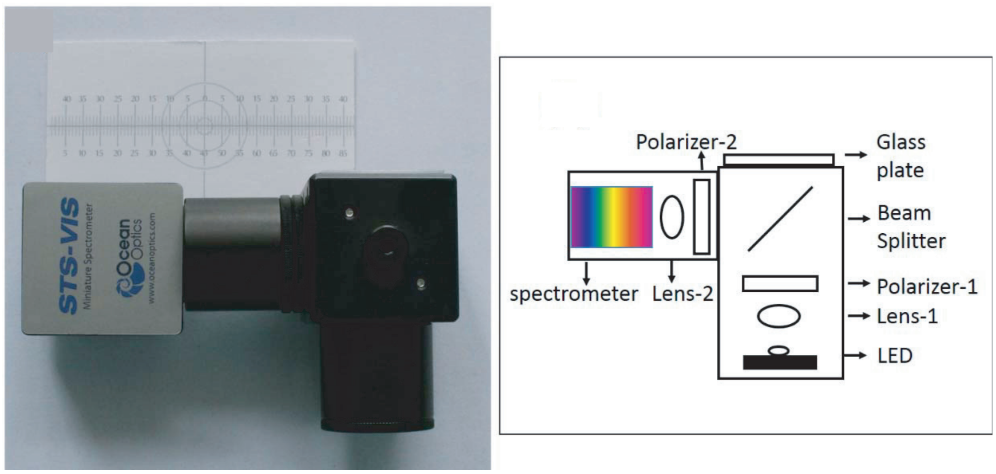
rate. A CM1-DCH/M (Thorlabs) is applied as the beam splitter holder. A glass plate, which is served as sample holder, is pasted to the top of CM1-DCH/M. A LED is pasted toSM1CP2 (Thorlabs), which connects to another SM1L10. In this SM1L10, there are also a lens (Lens-1 in Fig. 1(b)) and a polarizer. This lens is utilized to collimate the LED light. The utilization of polarizers herein is to reduce the interference of specular light. In the current system, all the optical devices are compatible with each other very well. Researchers can easily build a similar spectral detection system.

The main body of the electric device is a Raspberry development board, which is compatible with STS spectrometer. The USB port of Raspberry development board is served as the LED driver. A traditional PC can also be used to drive the system.

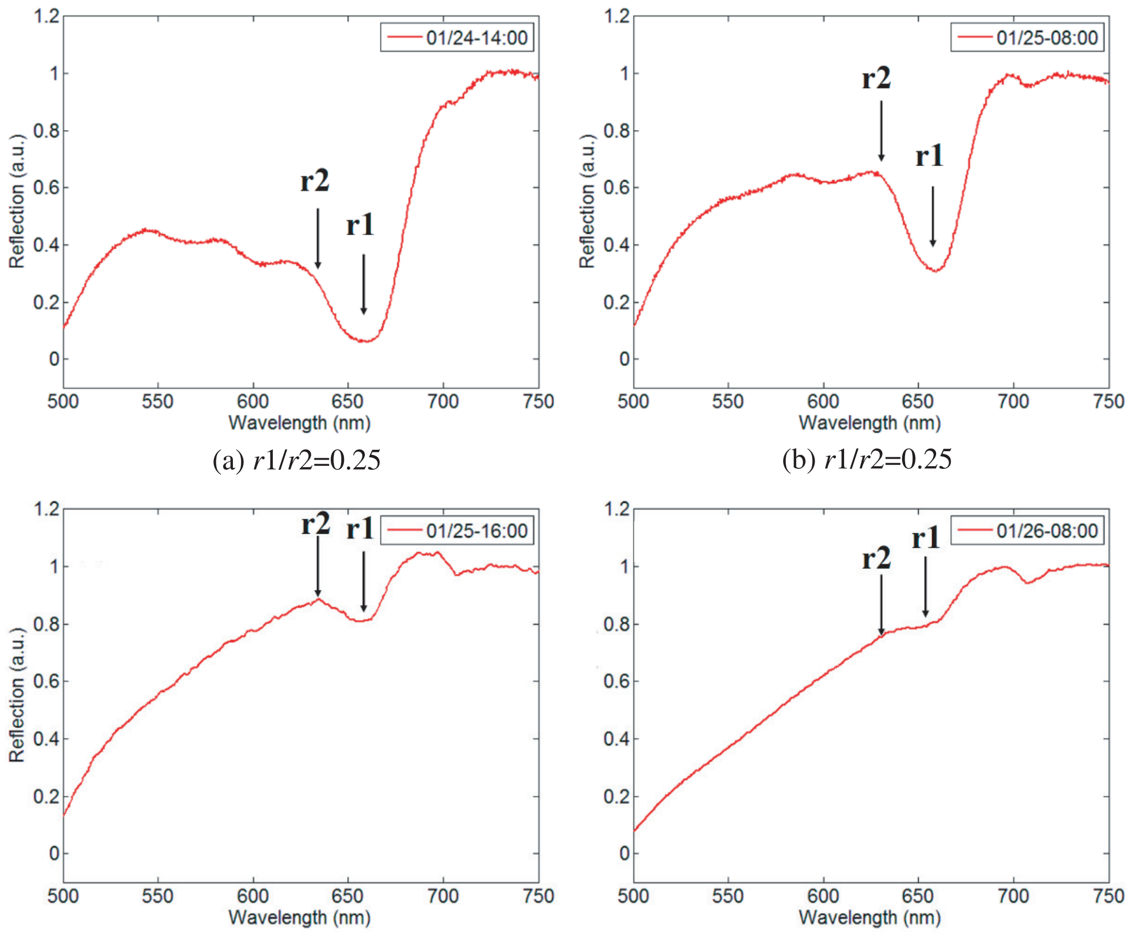


(a) (b)

Figure 1. (a) Photograph of a working prototype for the portable spectrum detection system. (b) The optical schematic. A white-light LED is collimate by an aspheric lens-1, and pass through a polarizer-1 and beam splitter. The glass plate is served as a sample holder. The reflection and back scattering signal from the sample is further reflected by the beam splitter and go through polarizer-2 and lens-2, then focus onto the slit of the spectrometer. The utilization of polarizers herein is to reduce the interference of specular light.

3. THE APPLICATION TO BANANA'S RIPENESS DETECTION

In order to verify the portable spectra detection system, we carry out reflection detection in a banana sample to test its ripeness [7, 8]. The ripeness of fruits can be correlated to chlorophyll [9]. Change of chlorophyll concentration leads to a variation in the reflection. The measurements were performed lasted two days.The results are plotted in Fig. 2. We can observe an obvious change in the reflection rate around 658 nm, which corresponding to the absorption band of chlorophyll [9]. In order to quantify this change, the reflection rates at 634.3 nm and 658.1 nm are defined as $r1$ and $r2$ (as indicated in Fig. 2), the ratio between $r1$ and $r2$ is utilized to demonstrate the ripeness of the banana. The original reflected spectrum can be defined as $R(\omega)$. The data plotted in this manuscript is $c \times R(\omega)$, and c is a constant. Our method is based on the spectroscopic signature from the ratio of reflection at different reflection bands; therefore, normalization of data has no effect on the results. As the banana becomes ripe, the reduction of chlorophyll results in the increase of ratio. Agricultural scientists can classify bananas based on this portable system. After acquiring the reflection data, the ratio of $r1$ and $r2$ has the potential to quantify the ripeness. This ratio factor is easy-to-use. There is no need to maintain the intensity of incident light and the integration time for spectrometer.



(a) $r1/r2$=0.25 (b) $r1/r2$=0.25

(c) $r1/r2$=0.91 (d) $r1/r2$=1.04

Figure 2. Banana ripeness detection. The portable spectrum detection system was utilized to measure the reflection of banana's surface. (a) When the banana was not quite ripe, its reflection spectrum presented a deep absorption band at 658 nm. (b) After 18 hours, the absorption at 658 nm got smaller due to the decrease of Chlorophyll. The absorption band at 658 nm gradually disappeared as time goes on (c)–(d).

4. THE APPLICATION TO REAL-FINGER IDENTIFICATION

This system can also be used in real-finger identification. Fingerprint detection is one of the most popular tools in the field of identification [10]. However, at present there are some lawbreakers, who use 'fingerprint film' to copy other people's fingerprints, then wear on their fingers to deceive the fingerprint detector. These fingerprint film, which are close to the body's optical properties, are not easy to identify by simple detection tool. Fingers full of blood, and if a finger pressed a glass plate heavily, the surface of finger turned to 'pale'. However, unlike real finger, the fingerprint film is not a living organ, and its optical properties remain unchanged no matter how hard it presses the glass plate. Based on this observation, adynamic optical testing method is introduced to distinguish real-finger from fingerprint film.

In order to illustrate our method more clearly, some definitions are described as follows: The local maximum for reflection between 550 nm and 565 nm is denoted as $r1$, another local maximum for reflection between 585 nm and 600 nm is denoted as $r2$, and the local minimum between 565 nm and 585 nm is denoted as $r3$. The result of equation $(r1 - r3)/(r2 - r3)$ is defined as reflection factor.

In the dynamic optical testing method, volunteers were asked to press the glass plate twice, lightly

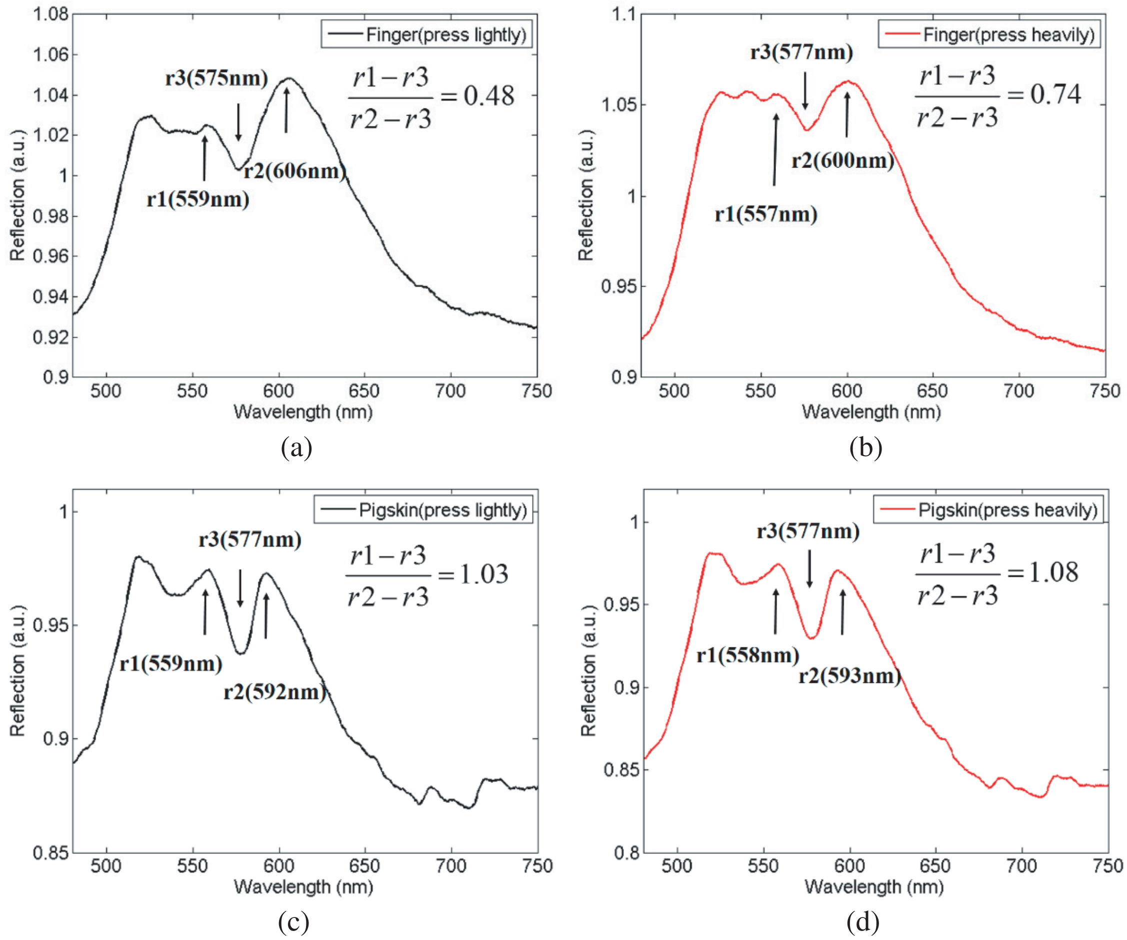


Figure 3. (a)–(b) In-vivo reflection detection for human finger. The reflection spectra shown in (a) and (b) are detected when the finger press the glass plate gently and heavily respectively. When the finger press the glass plate lightly, the color of finger surface is red, then the reflection around 600 nm is dominated. As the finger press heavily, this dominant gradually weakened. (c)–(d) Control experiments: Reflection detection for pigskin. In this case, the relationship between the reflection and the press action is not noticeable.

for the first time and heavier for the second time. Accordingly, the reflection spectra of volunteers' fingers were acquired. Two detection spectra are shown in Figs. 3(a) and (b). When the finger is placed on the glass plate 'lightly', the surface of finger appears relative red. In the spectrum from Fig. 3(a), the reflection at the red band is relative high, and the reflection factor is 0.48. When the finger pressed the glass plate heavily, the surface of finger turned to more 'pale', and the reflection peak around the 600 nm was reduced. This time, the reflection factor increased to 0.74. The difference between the above two reflection factors is 0.26. Five volunteers repeated the above experiments, and the differences were all larger than 0.2.

In order to demonstrate the valid of the dynamic optical testing method, control experiments were carried out on a pigskin. A finger pressed the glass plate through pigskin, served as a fingerprint film. The corresponding experimental results are shown in Figs. 3(c) and (d). No significant changes were observed in the spectra, and the difference between two reflection factors (as shown in Figs. 3(c) and (d)) is 0.05. Five pigskins were used to repeat the above experiments, and the differences were all smaller than 0.06.

Therefore, the reflection factor can be applied to distinguish real-finger from fingerprint film. During the dynamic optical testing, if the change of reflection factors is larger than 0.1, the sample can be identified as real-finger; otherwise, it is a fingerprint film.

5. CONCLUSION

A portable spectra detection system is demonstrated in this paper. This system is designed to be compact and efficient. After deriving the reflection spectra by this system, some simple and effective data processing was performed to identify the ripeness of banana and real-finger. The quantitative data agree well with the properties of the detected objects. On the basis of the overall results here reported, the portable device and simplified data processing methods have a huge advantage in application to in-site and real-time detection.

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