Near infrared imaging: new hardware opens new opportunities

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Introduction

Multispectral, or hyperspectral, imaging deals with observing a scene with a camera not only sensitive to visible radiation, but also to either ultraviolet (UV) or infrared (IR) radiation. Remote sensing excepted, very few experiments have been conducted. Using a CCD camera and a rotating filter wheel, Taylor and McClure[1] determined water depth and detected defects on tobacco leaves by combining images taken at 670, 800 and 990 nm. Robert *et al*.[2] combined a tube camera with a monochromator to discriminate different cereal components (starch, gluten and bran). Bellon *et al*.[3] showed that a combination of both visible and near infrared (NIR) wavelengths enabled the detection of defects on apples, whereas their detection by visible light only is impossible. In a similar approach, Upchurch *et al*.[4] combined NIR and visible image to detect bruises on apples. Park and Chen[5] used multispectral imaging (542–847 nm wavelengths) for discriminating unwholesome from wholesome poultry. More recently (1998), Muir *et al*.[6] applied multispectral imaging to detect diseases on potatoes.

We have applied NIR imaging to various vegetal products, using an InGaAs camera. This camera, sensitive from 900 to 1700 nm, is well adapted to detect defects on apples, stalk in grapes, but also the moisture gradient of blotting paper.

Materials and methods

Materials

The Sensor Unlimited camera has a 128 × 128 pixel Focal Plane Array made of InGaAs. This allows the camera to cover the 900–1700 nm range with a quantum efficiency over 65% from below 1.0 µm to beyond 1.6 µm. The camera, stabilised at 20°C, does not need any cryogenic liquids or limited life mechanical coolers and, thus, is well suited for field or industrial applications. The A/D converter has an 8-bit output with 1 count per 104 photoelectrons. Four 50 W halogen lamps are put at the four corners of a bell-shape lighting chamber designed to deliver diffuse light.

Methods

After having tested the stability of the camera, two types of experiments were conducted. For the first experiment, the aim was to detect features and defects which are difficult to discriminate with colour (red, green and blue, RGB) imaging. RGB and NIR images of grapes and apples were recorded.

In grapes, the aim was to distinguish between berries and stalk, because this is a useful feature to assess the grape compactness. Several defects can affect apple quality. For instance, russeting is a

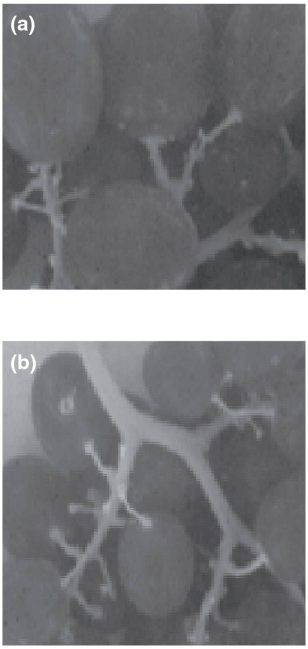

Figure 1. Grape images recorded with the NIR camera; (a) dark grape and (b) green grape.

cork-like surface which invades the skin; bitterpit is a beneath-the-skin necrosis of the flesh which appears as numerous grey surface deflections.

In the second experiment, two samples of blotting paper are wetted (by pouring water) and then allowed to dry. During drying, NIR images are recorded and the moisture content of the blotting paper sample is determined by the gravimetric method. As it takes around 250 minutes for the paper samples to become dry, images are taken every 30 minutes. For each image, the grey level histogram is computed, and then its average and standard deviation.

Results

Grapes

Figure 1 shows NIR images of dark and green grapes. These images show that distinguishing between the stalk and the berry is obvious using an NIR camera. This is due to the high amount of water in the berry, which absorbs NIR radiation. In the case of dark grapes, visible cameras could have done the job. In green grapes, it was impossible to distinguish between berries and stalk using just RGB cameras. Figure 1(b) also shows that stains can be seen using NIR images. However, it is not possible to distinguish between stain and dirtiness.

Apples

Figure 2 shows the RGB and NIR images of an apple having a large area of russeting. The russeting can easily be seen on the RGB image but not on the NIR image. However, the NIR image outlines the

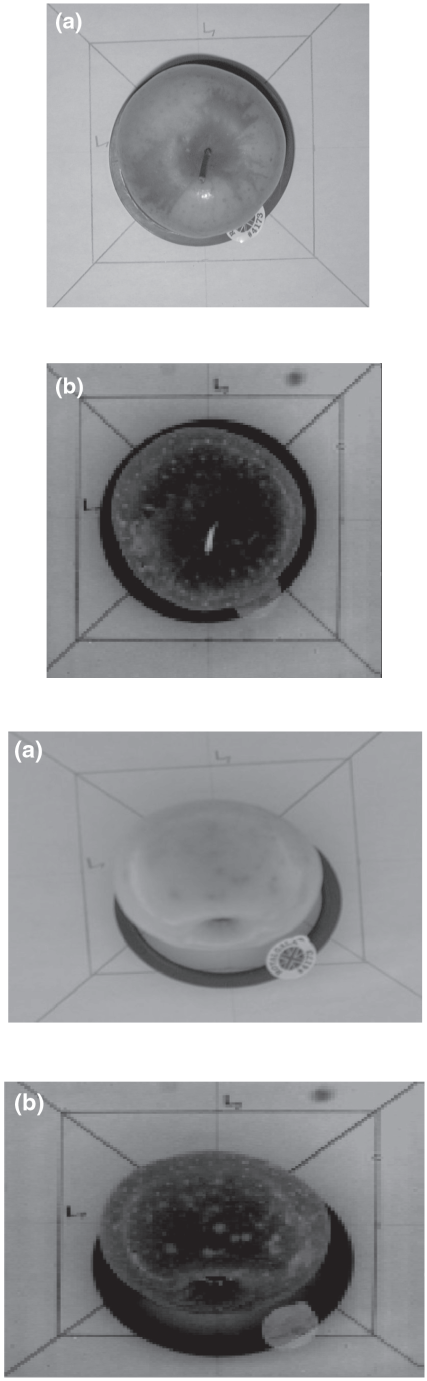

Figure 3. Images of a Golden Delicious apple presenting bitterpit: (a) RGB and (b) NIR images.

stem very clearly. Stem detection is very useful because stem can be confused with both russeting and bruises. That is why no commercial apparatus is really reliable.

Figure 3 presents the RGB and NIR images of an apple subject to bitterpit, which appears as dark spots on the lower part of the apple. In NIR images bitterpit can be seen as white spots. As bitterpit necrosis creates dehydrated spots under the skin, the latter appear white to the NIR camera. This application is of prime interest because bitterpit is absolutely impossible to distinguish in an industrial application using an RGB camera.

Humidity tests

The images of the drying samples are presented in Figure 4, showing their amount of humidity. The darker the image, the more humid the sample. Figure 5 is the graph of the average and the standard deviation of the grey levels of each image. A sigmoïd-shape function appears, which is typical of saturation phenomena: for too-high and too-low moistures, the camera is saturated.

Another remark is the big standard deviation. This can be explained by bright and shadowed surfaces created by an irregular illumination, or by the fact that the different fibres of the paper dehydrate at different speeds.

Figure 4. NIR images of dehydrating blotting paper samples with their moisture content as an overlay.

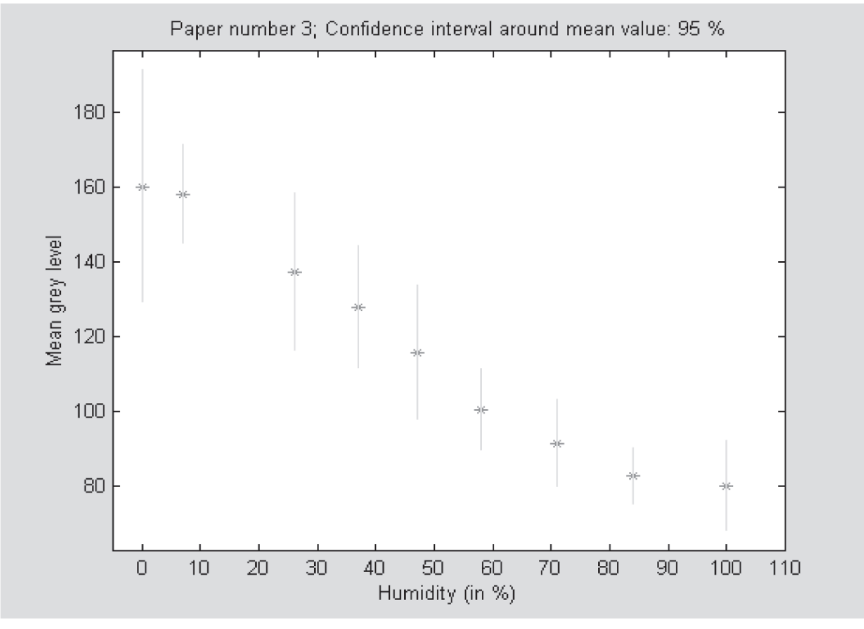

Figure 5. Average of the grey level histogram v. the moisture content of the paper samples. The vertical lines are the standard deviations, the stars are the mean values.

Conclusion

An NIR camera, sensitive in the 900–1700 nm range, has been used either to find defects or features in fruit or to quantify moisture of blotting paper. As NIR is absorbed by water, this camera is perfectly suited to determine features which present differences in water content: stalk can easily be differentiated in green grapes, which is impossible with RGB vision; apple bitterpit is clearly seen because it creates a light dehydration under the skin; apple stem is identified due to its low water content. For moisture content analysis, the grey level average versus the water content provides a sigmoïd-shape curve. In the linear range, it is usable to determine moisture even if the pixel-to-pixel analysis shows high variations. These NIR cameras open new opportunities: mapping food composition (for instance with regard to water), detecting foreign bodies or defects. These cameras are still expensive. Nevertheless prices are expected to drop due to the component transfer from military to civil applications.

References

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