Monitoring the internal quality of potatoes by NIR transmission and reflection measurement

M.T. Känsäkoski,[a] P. Suopajärvi,[a] V. Heikkinen,[a] R. Mitikka,[a] R.P. Chalucova,[b] G.P. Krivoshiev,[b] and H. Vasama[c]

[a]*VTT Electronics, PL1100, 90571 Oulu, Finland*

[b]*Institute for Horticulture and Canned Foods, 154 V. Aprilov Blvd., Plovdiv 4000, Bulgaria*

[c]*Suomen Optomekaniikka, Palokka, Finland*

Introduction

The internal quality of potatoes and other vegetables and fruits is an important quality factor for both consumers and food industry. There are several diseases and defects, which have no effect to the quality of potato skin. Therefore internal defects remain invisible to human and also to ordinary camera. Potatoes can be divided roughly to three different quality groups: no defects, minor defects and badly defected. The first quality group potatoes are used in products where visual look is important (e.g., chips or should they be called "freedom fries"). The second quality group potatoes are suitable for consumption, but they have reduced quality and they are further processed. The last quality group of potatoes is unfit for consumption and will be used for example in ethanol production. Therefore it is essentially important to sort potatoes on-line to increase the quality of sorted potatoes intended for sowing, retail and industrial processing. We will describe here a novel technique and instrumentation, which allows us non-destructively to 'look inside' the potato and define the internal quality of the potato from a continuous flow of potatoes on conveyor belt. This technique was originally developed at the Institute of Horticulture and Canned Foods.[1,2] This new instrument uses five different short wave near infrared (NIR) wavelengths for the measurement. The transmission and reflection of near infrared light from potatoes are measured from several different angles. The total number of measurement channels is sixteen. We will describe the optics and signal processing of this instrument and first test results.

V-camera instrument

V at V-camera stands for "virtually peeling". In this method and technology the potato, or other skinned fruit or vegetable, is virtually peeled by measuring the NIR transmission of potatoes and simultaneously measuring the NIR reflection from the potato skin. This method has been explained in details earlier in NIR news.[3]

Figure 1 illustrates the process flow of measurement, classification and sorting of potato tubers.

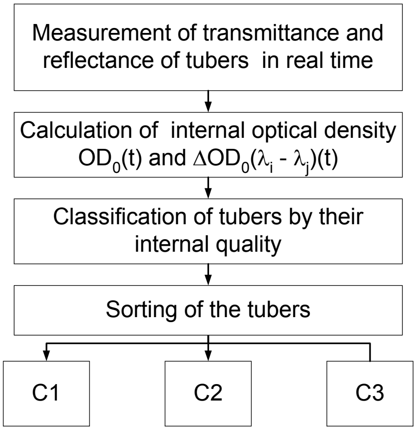

Figure 1. Flow chart of potato sorting process.

Potatoes are measured when they drop from the end of the conveyer belt (the measurement can be performed on the conveyer belt, too). When potato falls and enters to measurement zone it attenuates the signal from light source. This rapid attenuation is detected with detector, which is just opposite to the light source. Then the OBJECT PRESENT signal is created. This signal triggers the measurement cycle, which consists of "slices" of potatoes. The slice length is typically around 1ms (equals to 2-3 mm slice of potato). These slices are measured at three different wavelengths and 2Rx2T geometry (two reflectance $0^o/45^o$ geometry and two transmittance $0^o/135^o$ geometry channels). Totally this equals to 12 different measurement channels. Also the "back" side of the potato is measured by reflectance geometry with two wavelengths. When the potato has passed the measurement zone the OBJECT PRESENT signal is resetted. During the time between falling potatoes a standardisation value is measured at two wavelengths with a detector, which is just opposite to the light source. Total number of measurement channels then equals 16.

One measurement slice consists of series analogue to digital conversion (ADC) operations. Different measurement channels are measured sequentially (interval 1.6 µs). Within the time available for one slice this cycle is repeated n (n=slicetime/(16*1.6 µs)) times and the subsamples of each measurement channel are averaged.

The logical components of the measuring system

The major logical components of the system are (Figure 2):

- Light sources/optics with control electronics
- Detectors (transmission/reflectance) and preamplifiers
- Data acquisition synchronisation
- Data acquisition
- Optics and mechanics
- Features extraction
- Classification
- Sorting

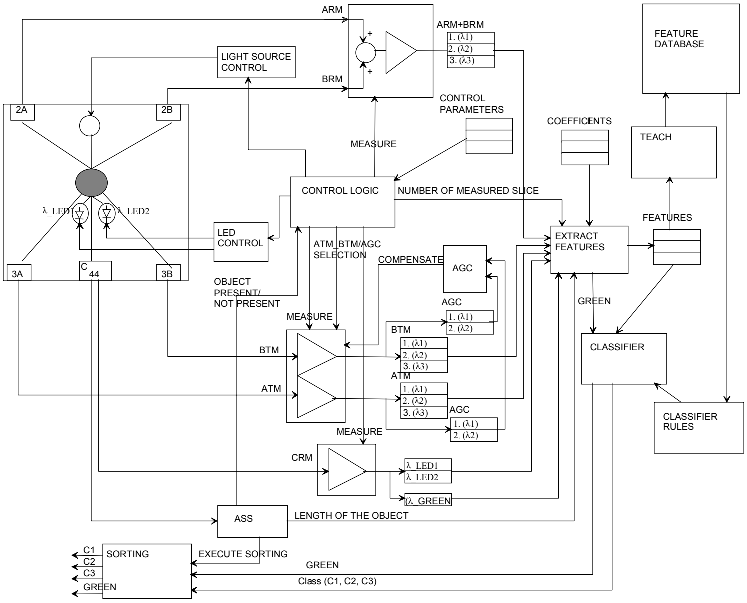

Figure 2. The main logical components of the V-camera system

Electronics: light source, detectors and data acquisition

Light source is a halogen lamp and detectors are silicon (Si) photodiodes. Preamplifiers are transimpedance preamplifiers without bias. This kind of arrangement is especially suitable for low frequency photometric applications (as is the case in V-camera). Data acquisition is based on PC/104 standard I/O board developed at VTT Electronics (ReMix/104, block diagram is presented in Figure 3), which is connected to a PC/104 processor board. Some of the signal processing (e.g., subsample averaging and reflectance channels summing) is performed on ReMix/104. Classification is done on PC/104 processor board. This kind of arrangement is very flexible and in future allows us to implement easily more complicated classification routines.

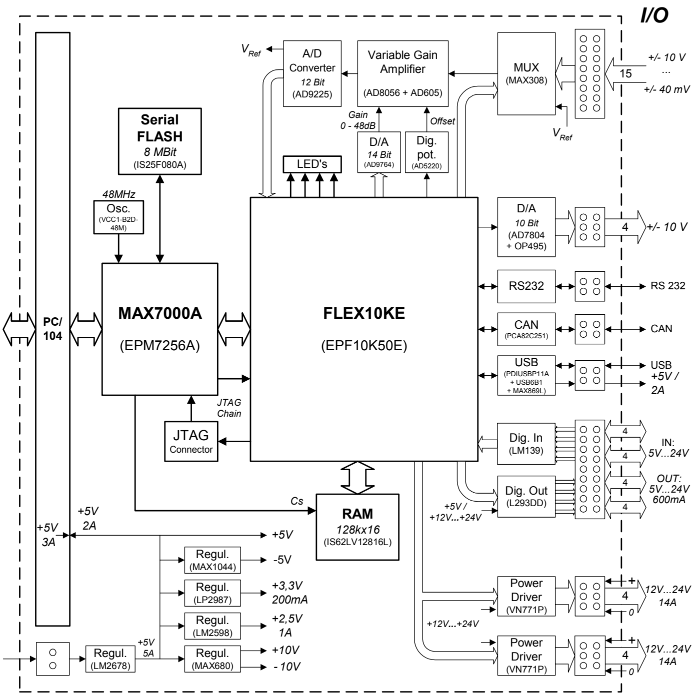

Figure 3. Block Diagram of ReMix/104 - reconfigurable I/O subsystem PC/104 expansion module

Optics and mechanics

The optical construction of illumination unit is simple and robust. The only components are light source, elliptical mirror, window and target.

A 3-D model of the optics was built to optical design software and all simulations were carried out with the real construction of all optical and mechanical components. The simulations proved that the optics behaves as designed, Figure 4. One of the main issues in the illumination unit was to ensure that as little stray light as possible is detected by measurement channels. In that sense this construction is simulated to work well. The mechanical 3-D model of the illumination unit is presented in Figure 5.

To minimise the chromatic aberration of the system also the detection optics was designed using mirrors in stead of lenses. This also gave free hands to place the components and to reduce the size of the construction.

The detection optics of the system is more complex, since each measurement geometry needs its own optics and each of these consists of three wavelength channels to be constructed. All wavelengths must be treated equally, so that changes in the measurement distance and intensity should not affect to the intensity ratios of different wavelengths.

The detection optics consists of two main parts:

- Spatial filtering part – all components before the aperture including it and
- Chromatic filtering – all components after the aperture.

A 3-D model of the optics was built to optical design software and all simulations were carried out with the real construction with all optical and mechanical components (Figure 6). The simulations proved that the intensity instability of the system is less than 5 % when the size of the target sphere (potato) was changed from 35 mm to 60 mm and 80 mm. It also proved that all wavelength channels have equal detection area and that the detector is large enough.

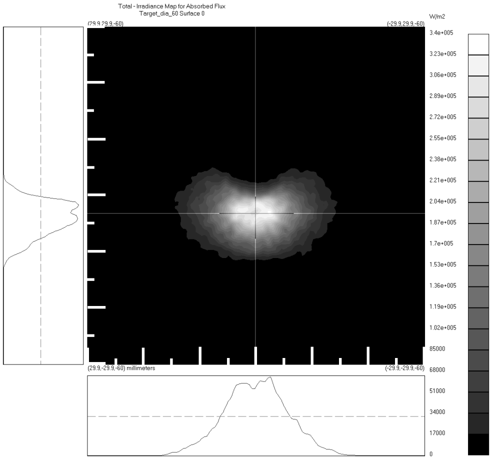

Figure 4. Simulated spot diagram of the illumination on spherical surface (image area 60 mm x 60 mm)

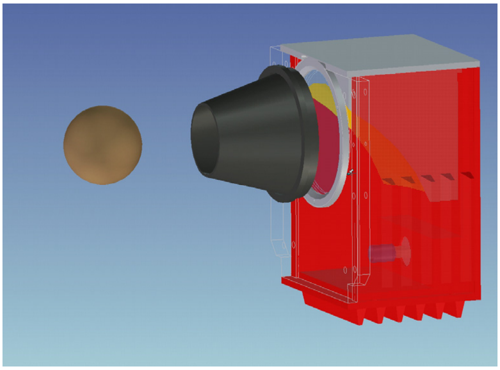

Figure 5. Mechanical model of the illumination optics.

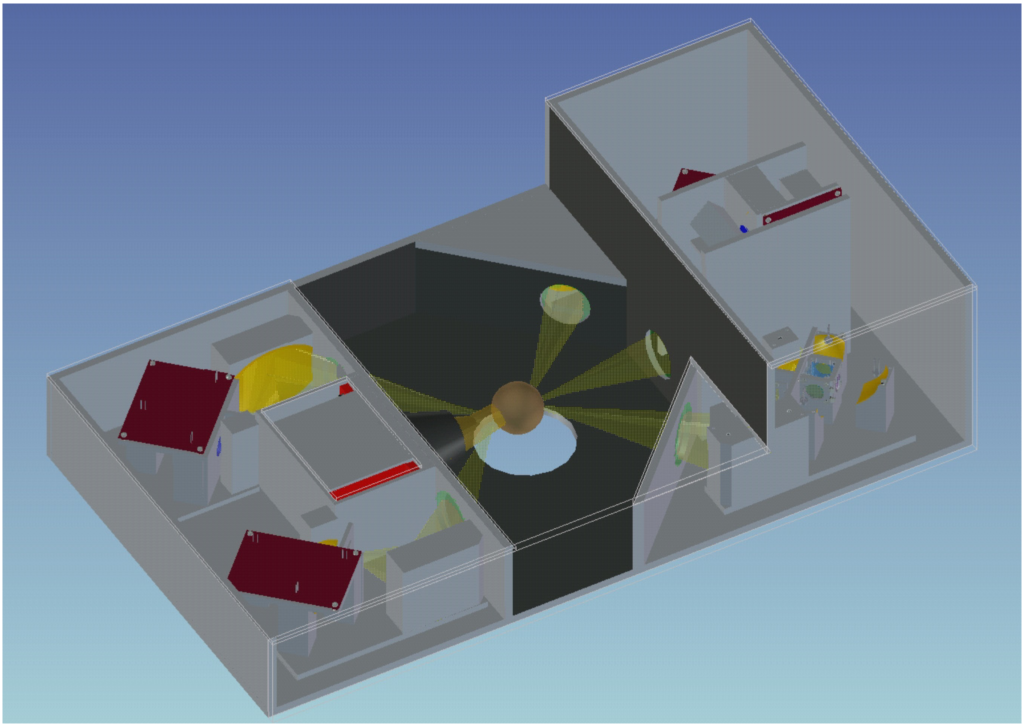

Figure 6. Mechanical model of the V-Camera combined with ray paths from optical simulation.

Measurements

In Figure 7 are signals from artificially defected potato measured by developed V-camera. Potato had a 4 mm wide black tape around the centre of potato. For clarity only transmittance and reflectance from one wavelength and one measurement angle are presented. Low reflection from the tape is clearly visible in the reflection signal and also the high absorbance of the tape is visible on transmission channel.

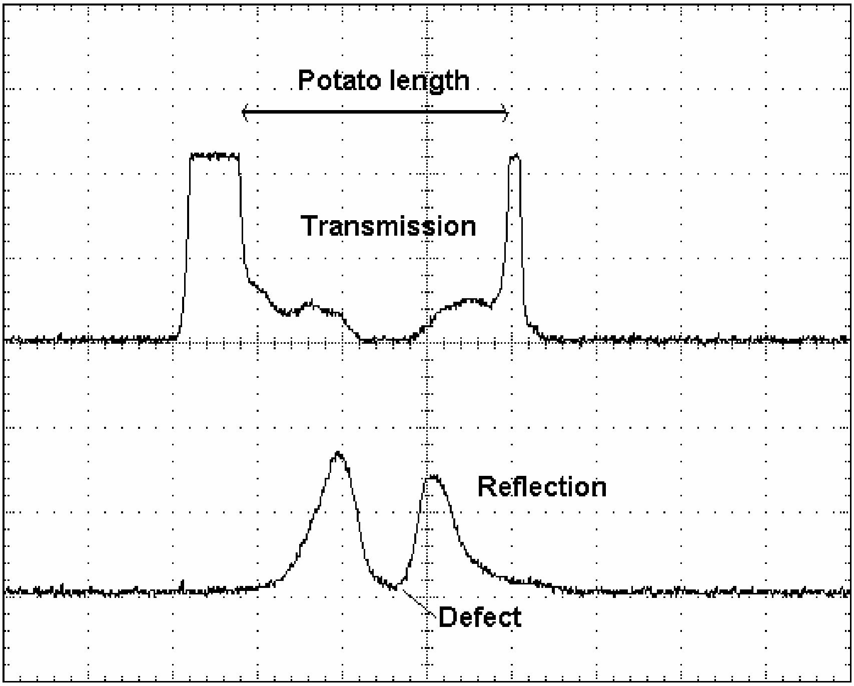

Figure 7. Transmittance and reflectance signals at one wavelength from a defected potato, defect at the centre of potato.

Discussion

First measurements with developed V-camera show that system has high signal to noise ratio. Also small defects are clearly visible. System will be tested in extensively with large set of potatoes and the capability to sort potatoes on-line will be demonstrated.

Acknowledgements

This project is funded under the Fifth Framework Programme of the European Commission, Thematic Programme *Quality of Life and Management of Living Resources*, Key Action 1 *Food Nutrition and Health* (Project QLK1-2000-00455). The authors thank Petar Bojilov Ir. for his active participation and valuable suggestions in discussing the camera design.

References

1. G. Krivoshiev, Bulgarian patent BG No. 101 069 (In Bulgarian), (1996).
2. G. Krivoshiev, R. Chalucova, M. Moukarev, Lebensm.-Wiss. Technol. **33(5),** 344 (2000).
3. G. Krivoshiev, R. Chalucova, M. Moukarev, NIR news **11(5),** 7, (2000).