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Telemetry for spectrometric quality determination in field

The quality characteristics of fruit and vegetables during their development are continually influenced by changes associated with surrounding conditions. To determine optimum harvesting time, e.g. for apples, information is required regarding the fruit ripening progress. Spectral optical measurements in visible and near-infrared wavelength ranges are suitable for rapid and damage-free recording of such changes in quality. Commercially available spectrometers are, however, mainly developed for laboratory measurements and too expensive and complicated for application in practical horticulture. A possible alternative is offered by portable spectrometers with telemetric data transfer.

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Apple quality depends on ripeness development during harvest and post-harvest conditions (length of storage and storage climate). For harvesting at optimum time, continuous control of ripeness development up to harvest is necessary [1, 2]. The ripeness development is associated with degradation of chlorophyll and decomposition of starch to sugar and can be identified through analysis of fruit tissue composition. For determining optimum quality for harvesting, storage and marketing it must be possible to determine these qualitative alterations under field conditions and without damage to the fruit. Seen as a promising method are spectroscopic measurements in the visible and near-infrared wavelength range [3]. Spectrometric tests with apples during harvest and post-harvest period in the wavelength range from 400 to 1000 nm confirmed this assumption. [4, 5].

Technical concept

Cost-efficient miniature spectrometers with glass fibre sensors applicable even in raw conditions have been available for some time. The possibilities of applying this technology in horticulture were the subject of an ATB project with the aim of developing a practical sensor system for flexible data recording outdoors.

The system is modularly constructed with standard components. The user should be able to carry the spectrometer with him and measure characteristics of fruit with full freedom of movement by simply applying the sensor head to the fruit. While the sensor action is in total automatically controlled, the operator manually selects for individual measurements. The measurement data is transferred to a stationary notebook PC per wireless telemetry and stored on the main disc. Optionally, it should also be possible to send spoken information from the operator to the notebook PC over an additional telemetry system.

In *figure 1* the complete construction of the telemetric measurement system is schematically presented. The portable part-system can be run for over eight hours with a powerful NiMH accumulator. An MMS1-NIR enhanced (ZEISS Jena) monolithic miniature spectrometer module is used as spectral sensor onto which differently-specific sensor heads adjusted to suit the fruit can be fi-

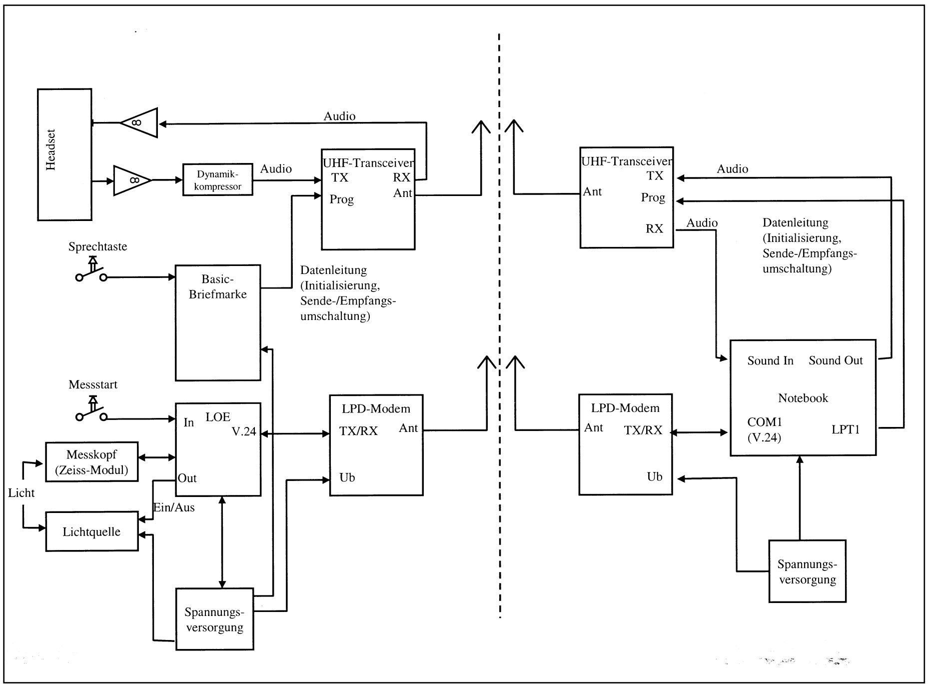

Fig. 1: System design of complete spectrometer

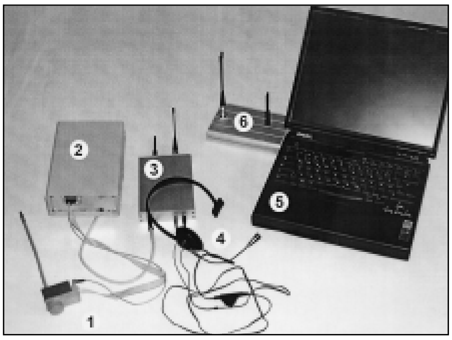

Fig. 2: Components wireless spectrometer system: 1 – spectrometer module (Zeiss MMS1), 2 – controlling electronics (incl. accumulator), 3 – data and audio transceiver, 4 – headset, 5 – notebook PC, 6 – data and audio transceiver

ted with glass fibre bundle and optical standard connections. Light source – normal or halogen lamps can be applied – and the spectrometer are electronically controlled over a LOE control unit (tec5 Oberursel). From the control unit the measurement data is transferred to an HF LPD (low power device) modem (OPC Cologne) transmitting in the 2.4 GHz ISM band *(table 1)*.

The data transmission takes place with the so-called Frequency-Hopping-Spread-Spectrum system to give high reliability. Outdoors, transmission can be over a distance from around 100 m.

Communication with the PC is planned over a number of keys as well as optionally via bi-directional audio interface with headset as in mobile telephone. The recording of spoken commentaries is via *.wav data together with the measurement data on the PC. The headset is usable as exit for acoustic answers (e.g. signal good, error, ...). Recorded commentaries can be played back through calling up the stored spectral-optical measurement data.

Software

For processing the spectral-optical measurement data an ATB-developed software is used. The spectral values of the tested fruit are calculated in relationship to the reference values of black and white standards:

M = R-B)/(W-B)

Table 1: Technical data of OEM modem OPC1515

Frequency range	2,405 to 2,477 GHz (ISM Band: Industrial, Scientific and Medical
Com port	RS232, (8/N[/E/O]/1)
Baud rate	9,6 to 230,4 kbps
Electricity supply	5V, ~ 200 mA
Measurement area	60 mm x 45 mm x 15 mm
Antennae connection	SMA
Registration	in Europe: I-ETS 300440

R....value of raw spectrum of measurement object

B....value of raw spectrum from black standard

W....value of raw spectrum from white standard

M....calibrated spectral value of measurement object

Figure 3 qualitatively shows the typical spectral sensitivity curve of the system from spectrometer and halogen bulb. The sensitivity, dependent on the wavelength and on the limits of the spectral range from 300 to 1000 nm, is very low.

The integration time of the spectrometer is a control parameter automatically applied. Too high signal values (signal limitation) as well as too high interference near the limit of the spectral range must be avoided. The developed spectrometer software automatically realises up to three measurements with different integration times. For this, the spectrometer spectral range is divided into up to three sections with different signal amplitudes from which each is measured with a suitable integration time. Finally these three divisions are then joined together again to a continuous spectrum.

The software creates ASCII tables with the spectral-optical measurement data which can easily be further processed with tabular calculation programs such as MS Excel. Additionally, CIE Lab colour values are calculated and also added to the tables.

After activating the spectrometer component groups and starting the program on the notebook PC the system is ready for action. The operator should first of all carry out a calculation against the black and white standard. (This calculation can later be repeated as often as required). After this, measurements can proceed by activating the key „measuring".

When the measured data appears atypical, the software gives a warning signal (acoustic or otherwise). The operator must then decide whether this section of data should be stored or the measurement be repeated. Where necessary, spoken commentary can be recorded through pressing the „record" key before activating the „storage" key.

Literature

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Fig. 3: Qualitative sensitivity characteristics