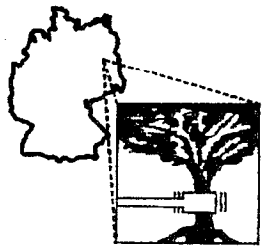

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Accurate sensing of bioinformation by optical method with multiband spectra and its structured data handling

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Abstract Stabilizing the cultivation of the agricultural products of high quality, the growth conditions of the plant should be well sensed and, therefore, the cultivation support system with high precision sensing function should be developed so that farmers can judge the optimum cultivation way based on the sensed information. Here we introduce a new challenge in the IT project on the agriculture which Ministry of Agriculture, Forestry and Fisheries in Japan does the initiative. We have been proceeding with the research regarding the various kinds of sensing technology to get the information arising on the field under the consciousness of this common problem, such as "Two-Dimensional Image Measurement System of Leaf Angle", "Three- Dimensional Image Measurement System for Plant Cultivation", "Laser-induced Fluorescence Spectroscopy (LIFS) Sensing in the Field", "Analytical System for Bioinformation with Database and Java Applet", and "Wearable Type Computer System for Referring the Sensed Information". Therefore the first purpose of this study is to construct the measurement system for acquiring growth information of crops using various sensors especially based on the optics technique with multiband spectra. It is also another large purpose that BIX (the abbreviation of BioInformation eXchange), which is the XML standard for the data exchange between sensed data of the information arising on the spot and database, is decided.

Introduction

We have been developing the cultivation support system. As for image analy- sis, color image processing and a new shape analytical method were proposed (Motonaga 1997, 1998). Comparison among the images of various rice varieties was made for the construction of database on rice plant type (Oka 1988, 2000). Texture analysis methods were applied to plant images to extract shaping features, and a new 3-dimensional measurement method of leaf tip angles was proposed (Shono 1994, 1996). In spectroscopic methods, IR spectroscopy for biomaterials, agricultural

products and foods (Kameoka 1998, Hashimoto 2000) and the application of IR spectroscopy on the non-destructive measurement of agricultural products (Ishizawa 2001) have been studied. Laser-Induced Fluorescence Spectroscopy (LIFS) has been applied to atmospheric remote sensing, vegetation monitoring and the monitoring of agricultural products (Saito 1998a, 1998b). Bioinformation analytical system on the Internet was developed (Motonaga 2000). For the application of video communication, remote examination system for plant diseases was proposed (Iguchi 1998, 1999).

The purposes of this study are to construct the sensing system for crops, and to discuss BIX (BioInformation eXchange), XML standard for the data exchange between sensed data of the information arising on the spot and database.

General concept of this project

The general concept with BIX was shown in Figure 1. Since our target is a single leaf to colony of crops, multiband spectrometers were used in the laboratory while LIFS and digital camera in the field. Various sensing and imaging method, and the mobile computer system for referring the sensed data were developed. We are now accommodating each sensing system to the mobile data processing based on BIX.

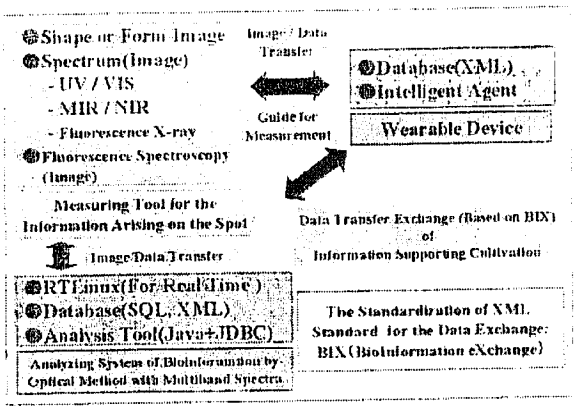

Fig. 1. General concept of this project

Results and discussion

Two Dimensional Image Measurement System of Leaf Angle

Rice plant image was analyzed to characterize the plant type. Figure 2 (a) shows the plant shapes of four rice cultivars. The percentage of the pixels showing plant body in each sub-area was averaged and a contour line of the shoot density was obtained (Fig. 2(b)). The leaf angle was calculated with a sequence of pixels extracted from the plant outline. The distribution was illustrated as Figure 2(c). Comparison of the numerical factors on the shoot density and leaf angle showed clear difference among the cultivars or the growing conditions. The plant type characteristics analyzed by this system would be disclosed on the Internet based on BIX for easy data access.

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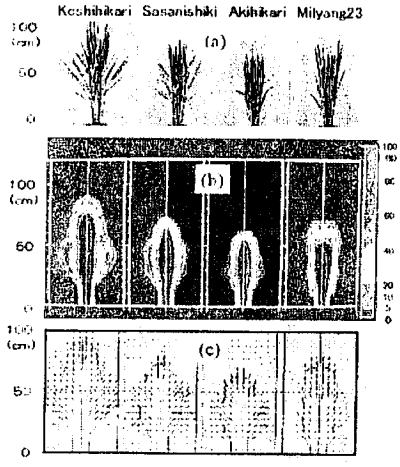

Fig. 2. Results of image analysis of four rice cultivars
(a) Photographs of plant shapes at the heading stage
(b) Two-dimensional distribution of shoot density of four cultivars
(c) Two-dimensional distribution of leaf angle of four cultivars

Three-Dimensional Image Measurement System for Plant Cultivation

An image measurement system, which can reconstruct a 3-dimensional distribution of leaf angle with images taken from several directions, was developed based on 2-dimensional FFT program and the CT algorithm. As an example of tomato plant, proper reconstruction was confirmed.

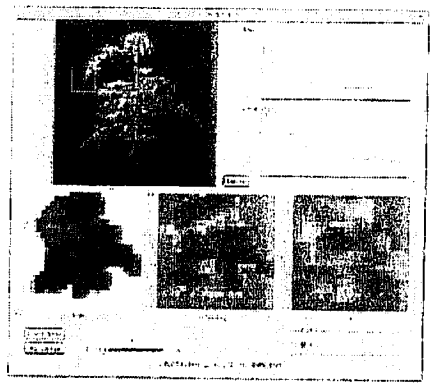

Fig. 3. Two-dimensional distribution of apparent leaf angles of tomato (bottom right)

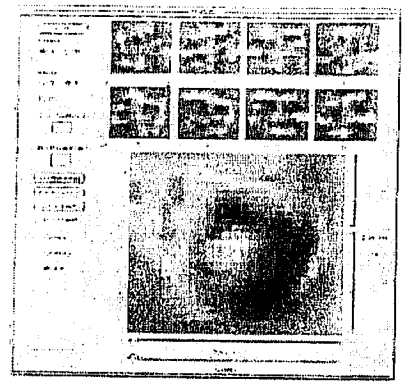

Fig. 4. Three-dimensional distribution of leaf angle, reconstructed with images from 8 directions

Figure 3 shows a 2-dimensional distribution of apparent leaf angles of tomato (bottom right). Figure 4 shows a 3-dimensional distribution of leaf angle, reconstructed with images from 8 directions. The bottom image shows horizontal section of the 3-dimensional distribution, where white pixels correspond to vertical leaves and black pixels horizontal ones. This method with digital camera automatically captures the plant images and gives the status of water potential

appropriately, which could be interpreted to the BIX based format and informed to remote farmer via Internet with the surrounding information, like temperature and moisture.

Laser-induced Fluorescence Spectroscopy (LIFS) Sensing in the Field

LIFS was applied to the non-destructive growth monitoring of Lettuce in the field. Figure 5 shows the developed system. In response to laser irradiation (355nm, 0.2mJ/pulse, 10ns, 10Hz), some organic pigments inside the lettuce leaves emitted fluorescence that was detected by an intensified CCD sensor through a spectrometer. Obtained data were saved into one computer then transferred to another one 15km away by a mobile phone. Figure 6 is an example of results with the ratio intensity at 460nm to 685nm. The comparison between concentrations of some organic compounds inside the lettuce, measured by HPLC, and the fluorescence data suggested a good correlation of the concentration of Chlorogenic acid with the fluorescence ratio. This shows that LIFS would be a powerful tool for the inside-living-status information. For the further application, obtained results should be directly informed to the farmers to predict the parameters of cultivation using database and model base based on BIX.

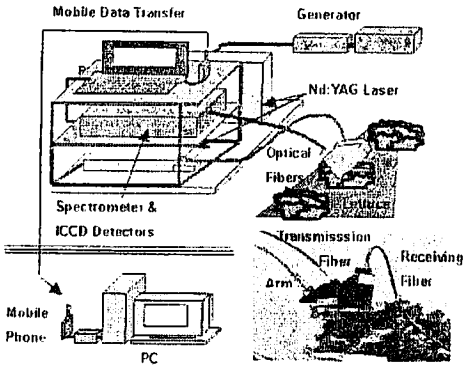

Fig. 5. Layout of laser-induced fluorescence spectroscopy system

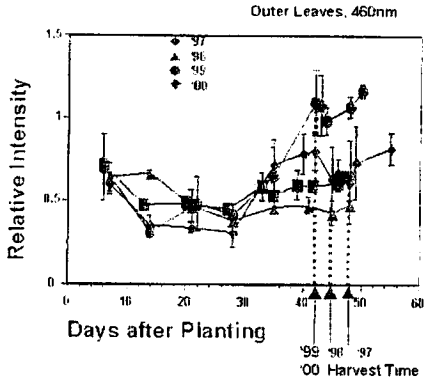

Fig. 6. Daily variation of the fluorescence intensity

*Analytical System for Bioinformation with Database and Java Applet*A quality analyzer of agricultural products was developed. Figure 7 shows the database constitution with data flow. Web server, database server and analysis tools programmed by Java applet integrated this system. Figure 8 shows an example of the execution screen of color tool. This tool provides the standard color image; shape one the average shape image; and spectrum analysis one spectrum processing. On the Internet, farmers can easily make a quantitative evaluation of their own products.

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The database enrichment and our sensing methods would enable farmers to diagnose the products in the field. Furthermore BIX might make it possible to open the information to the flow channel of the products and the consumers through the Internet.

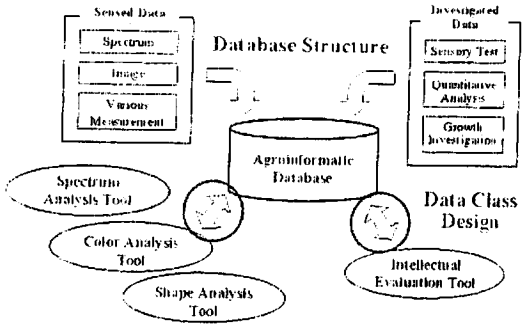

Fig. 7. Database constitution with data flow

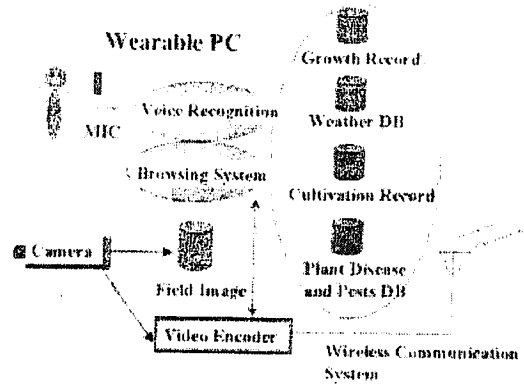

Fig. 8. Constitution of wearable computer system for aiding fruit tree cultivation

Wearable Type Computer System for Referring the Sensed Information

The system for aiding fruit tree cultivation was developed on wearable type computer (Fig. 9). Farmers can cultivate plants using the knowledge and information of this system. Figure 10 shows a snapshot of the display: sensed information area (top left), color image area with plant pictures (bottom left), graph area on a plant growth process(bottom right) and cultivation record area for each plant(bottom right). This bioinformation referring system works well for aiding a cultivation of fruit trees. For exchanging various kinds of sensed data, however, we need a uniformed format BIX for representing a bioinformation, which is effective over the Internet.

Conclusions

A diversity of the format of the information arising on the spot becomes large problem. In present state, each sensed data tend to be described in each special format for easy understanding and utilization. However, it frequently forces the correspondence to format information without the direct relationship in the data when others utilize it only for reference. It is not only at inefficiency like but also inconvenient. Therefore discussion on BIX is very important: and BIX of all information arising on the spot by opening the format to the public would be next large goal.

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