Fluorescence Imaging Based Machine Vision System to detect citrus defects

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Introduction

- Most citrus species contain substantial quantities of flavonoid substances and the peel of the citrus fruit fluoresces (FL) when the peel oil is released by some defects and can become visible when exposed to ultraviolet (UV).
- Our research focuses on developing fluorescence imaging-based machine vision systems, which are concerned with detecting surface defects of citrus fruits.
- However, the fluorescence emission from the object is a function of the angle and wavelength of the incident light and to acquire fluorescent image the importance of proper illumination for a machine vision system cannot be overstated.

Methods

- Firstly, for a lighting unit selection and its configuration for constructing machine vision system we investigated the best wavelengths for fluorescence excitation and the resulting fluorescence wavelengths for 15 common and popular varieties of Japanese citrus.
- Based on spectra information we design the fluorescence imaging-based machine vision system in order to detect the defective citrus fruits.

Results and Discussion

Statistical Analysis

- Figure 1: Results of applying principal component analysis (PCA) to the data.
- Figure 2: Results of applying discriminant analysis (DA) to the data.

Design of Image Acquisition System

Application: Citrus packing house

Application: Mobile grading machine

Conclusions

- Investigated the best WLs for FL EX and the resulting FL WLs in categorized citrus into four groups.
- Developed the FL imaging system and implemented successfully in the packing house.

Purpose

- To observe the spectral properties of citrus, at which excitation wavelength the peel of the citrus fluoresces properly to inspect the fluorescence regions.
- To categorize the citrus by variety based on the levels of fluorescence emission, in order to give some tips for optimizing the fluorescence imaging system.
- To construct the fluorescence imaging system based on the spectral study.
- To implement the system into packing house and mobile grading machine and as well for harvesting citrus at night time.

Table. Detailed information on the measured citrus varieties

<table>
<thead>
<tr>
<th>Variety name</th>
<th>Species</th>
<th>FL wavelength (nm)</th>
<th>FL intensity</th>
<th>FL group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amanatsu</td>
<td>C. reticulata</td>
<td>530</td>
<td>378</td>
<td>Strong</td>
</tr>
<tr>
<td>Dakepon</td>
<td>C. reticulata</td>
<td>534</td>
<td>376</td>
<td>Strong</td>
</tr>
<tr>
<td>Buntan</td>
<td>C. gigante</td>
<td>535</td>
<td>378</td>
<td>Strong</td>
</tr>
<tr>
<td>Seko</td>
<td>C. hystrix</td>
<td>533</td>
<td>378</td>
<td>Strong</td>
</tr>
<tr>
<td>Setoka</td>
<td>C. sinensis</td>
<td>533</td>
<td>376</td>
<td>Strong</td>
</tr>
<tr>
<td>Iyokan</td>
<td>C. yamato</td>
<td>531</td>
<td>377</td>
<td>Strong</td>
</tr>
<tr>
<td>Harumi</td>
<td>C. yamato</td>
<td>532</td>
<td>377</td>
<td>Strong</td>
</tr>
<tr>
<td>Navel</td>
<td>C. yamato</td>
<td>532</td>
<td>377</td>
<td>Strong</td>
</tr>
<tr>
<td>Setoka</td>
<td>C. hystrix</td>
<td>533</td>
<td>374</td>
<td>Medium</td>
</tr>
<tr>
<td>Yuzu</td>
<td>C. yamato</td>
<td>537</td>
<td>375</td>
<td>Medium</td>
</tr>
<tr>
<td>Navel</td>
<td>C. yamato</td>
<td>532</td>
<td>373</td>
<td>Medium</td>
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<tr>
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</tr>
</tbody>
</table>

Fig. FL spectra of weak group citrus

Fig. FL spectra of weak group citrus

Fig. FL spectra of weak group citrus

Fig. FL spectra of weak and zero group citrus

Fig. Results of applying principal component analysis (PCA) to the data.

Fig. Results of applying discriminant analysis (DA) to the data.

Fig. Citruses used for investigating spectral properties

Fig. Spectral Properties & Classification

Fig. Layout of the double image acquisition system

Fig. Machine vision units setup on the conveyor. Right: inside view of one unit

Fig. Acquired color and fluorescence images of one fruit passing through one unit

Fig. Results of applying principal component analysis (PCA) to the data.

Fig. Layout of the double image acquisition system

Fig. Layout of the mobile fruit grading machine

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