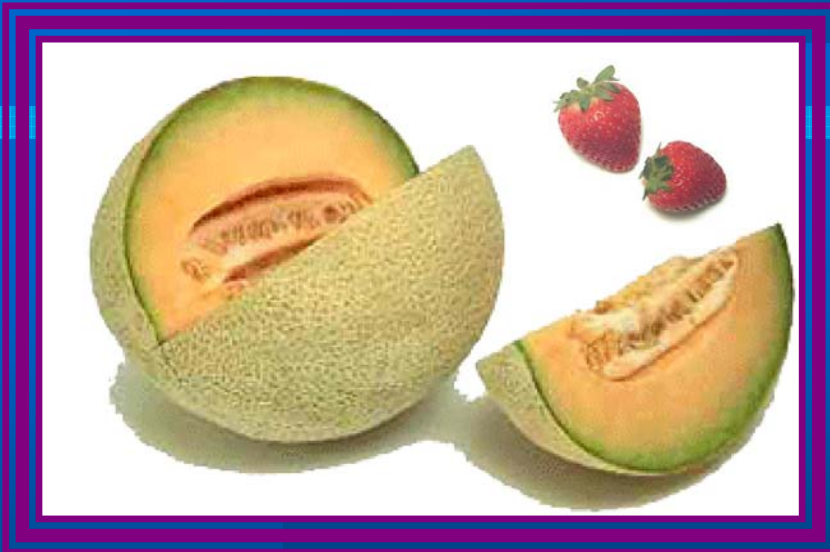# Safety Inspection of Fruit and Vegetables Using Optical Sensing and Imaging Techniques

Hyperspectral Fluorescence Imaging System for Food Safety
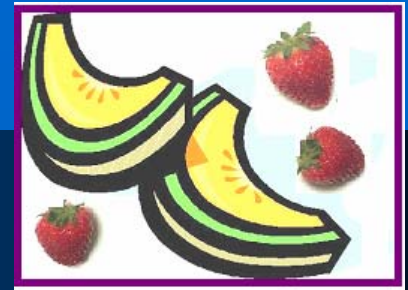
*Yang Tao*

Professor

Update on Research Supported by JIFSAN, 2004

Research Team

- **PIs:**
  - **Dr. Yang Tao,** P.E., Professor, Biological Res. Engineering, UMCP
- **Graduate Student:**
  - **Angela M. Vargas,** UMCP Graduate Research Assistant. Instrumentation and Sensing Lab, USDA/ARS
- **Co-PIs:**
  - **Dr. Moon Kim**, Scientist, Instrumentation and Sensing Lab, USDA/ARS
  - **Dr. Alan M. Lefcourt**, Scientist, Instrumentation and Sensing Lab, USDA/ARS
  - **Dr. Yud-Ren Chen**, Research Leader, Instrumentation and Sensing Lab, USDA/ARS Beltsville
- **Collaborators:**
  - **Dr. Yaguang Luo**, Scientist, Produce Quality and Safety Lab, USDA/ARS
  - **Dr. Robert L. Buchanan**, Senior Science Advisor, FDA CFSAN
  - **Dr. Yoonseok Song**, Research Scientist, Division of Food Processing and Packaging, Summit-Argo, IL, FDA NCFST

Background
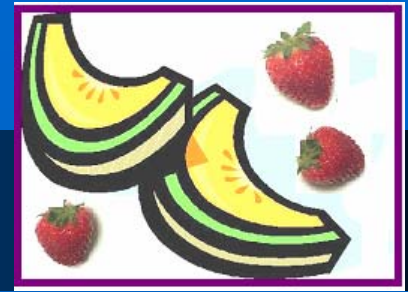
- Animal and human fecal matters are sources of pathogens such as *Eschericia coli, Salmonella* and *Cryptosporidium*.

- Outbreaks of foodborne illness associated with consuming raw fruit and vegetable in the US have occurred more frequently in recent years (FDA, USDA)

- Strawberries and cantaloupes are potential vectors of fecal contamination and foodborne illnesses.
    - Direct contact with soil.
    - Exposed to natural elements favoring pathogenic contamination.
   - Unsanitary condition during handling.

Background

- On October 2002 the FDA banned imported cantaloupe:
  - unsanitary conditions in the growing and packing.
  - 4 outbreaks of salmonellosis, including 2 deaths and 18 hospitalizations in 14 states.

pathogens to grow on the
upe, it is considered a
od.

- On April 1997 the FDA recalled ~1.7 M lb. of imported frozen strawberries after students in 6 states were exposed to hepatitis.

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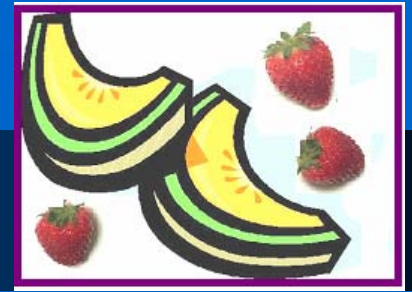
Previous Research

- Detection of fecal contamination on apples based on hyperspectral imagery.

- Multispectral laser-induced fluorescence imaging system for large biological samples.

- Multispectral fluorescence imaging.

- Equipment for removing apples with physical defects during sorting process in commercial settings.

Objectives
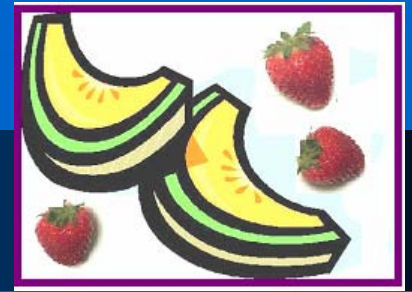
- To determine the spectral characteristics of animal feces on cantaloupes and strawberries to detect contaminated areas.

- To determine the optimal wavelengths of contaminated cantaloupes and strawberries using multi-spectral imaging.

- To study pattern recognition and detection algorithms.

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Materials and Methods

- Cantaloupes and strawberries from a local store were rinsed and allowed to air dry.

- Fresh COW feces collected from USDA dairy were diluted with H_2O to different concentrations by weight.

- A pipette was used to apply a range of dilutions to samples.

- Fluorescence images were taken.
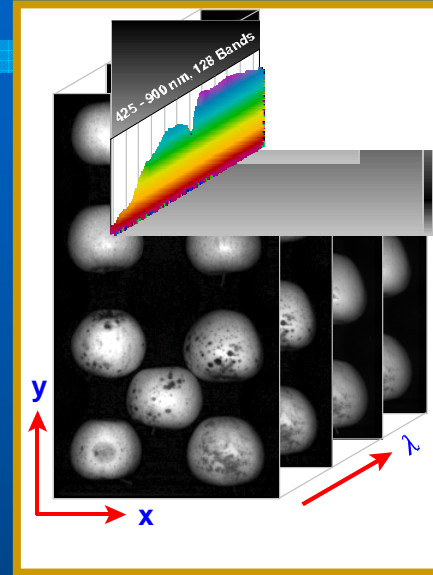
Sample Preparation
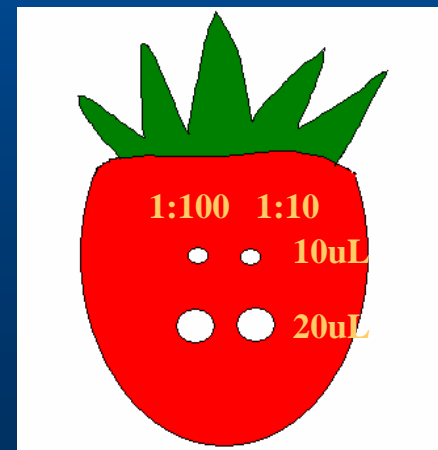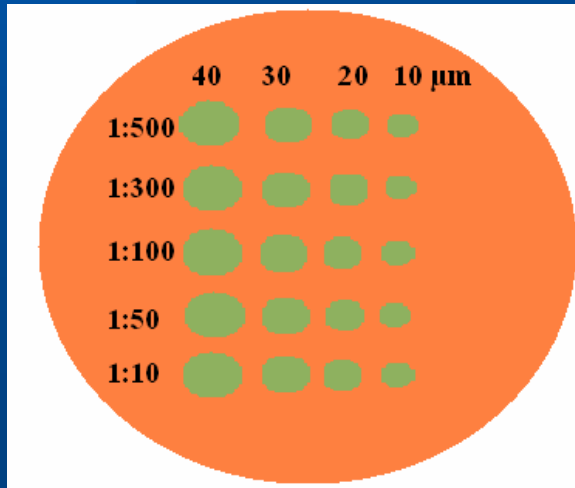
Equipment
Hyperspectral Imaging System (HIS)

Hyperspectral Imaging system
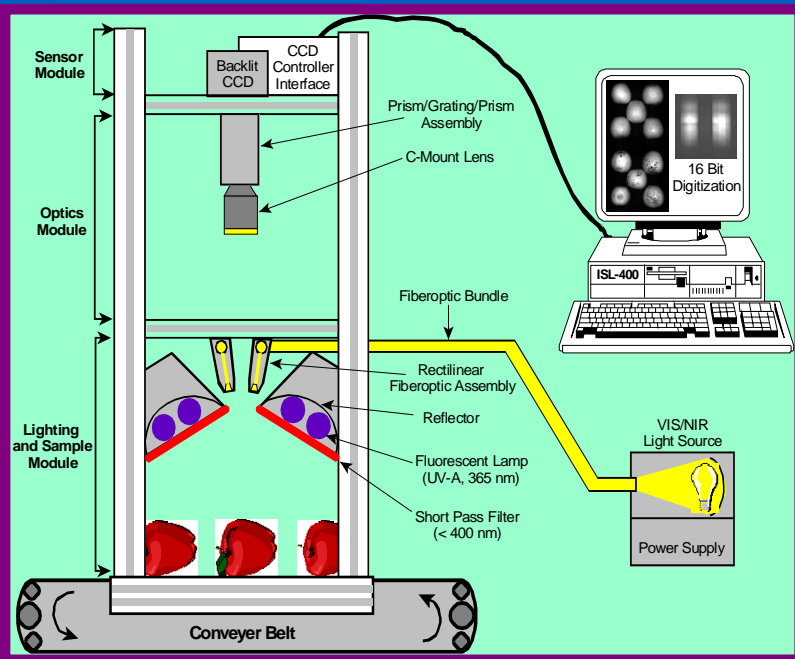
- The system consists of :
  - Light and sample module
  - Optical module,
  - Sensor module.

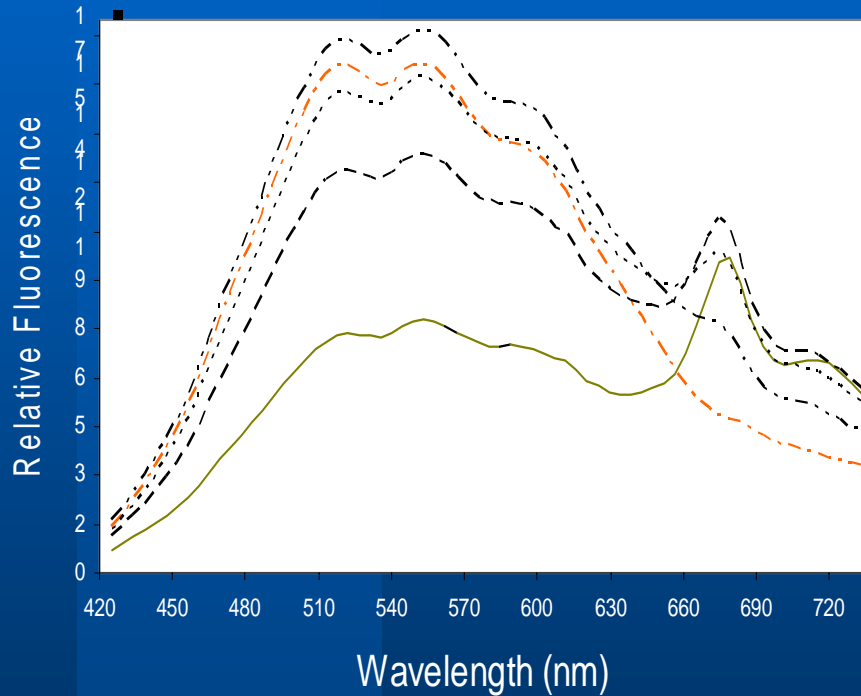- Line-by-line scanning spectrometer.
- Spectral range: 425-950 nm
- High spatial resolution: SR <=1 mm^2
- High spectral resolution: 2 nm bandwidth
- 112 channels, 4.5 nm interval.
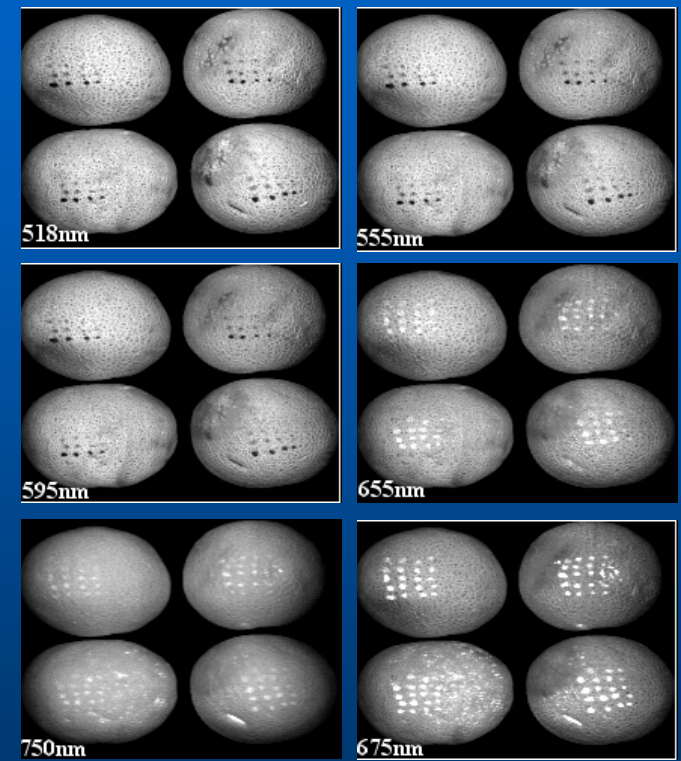- Dual illumination sources for fluorescence and reflectance.

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Approach

VIS/NIR Hyperspectral Reflectance Images

λj
λ_4
λ_3
λ_2
λ_1

Hyperspectral Fluorescence Images

Fluorescence Image processing

Multispectral Image Analysis and Transforms

Extraction of Contaminated Spots, Cracks, and Microbe Harborage

VIS/NIR Image Processing

Defect Curvature Image Transform

Database

Classification

Results

Relative Fluorescence vs Wavelength (nm)

■ Determine optimal spectral bands

■ Use for image processing

518nm 555nm 595nm 655nm 750nm 675nm

Legend: Control — (1:10 at 40uL) — (1:50 at 40uL) — (1:100 at 40uL) — (1:300 at 40uL)

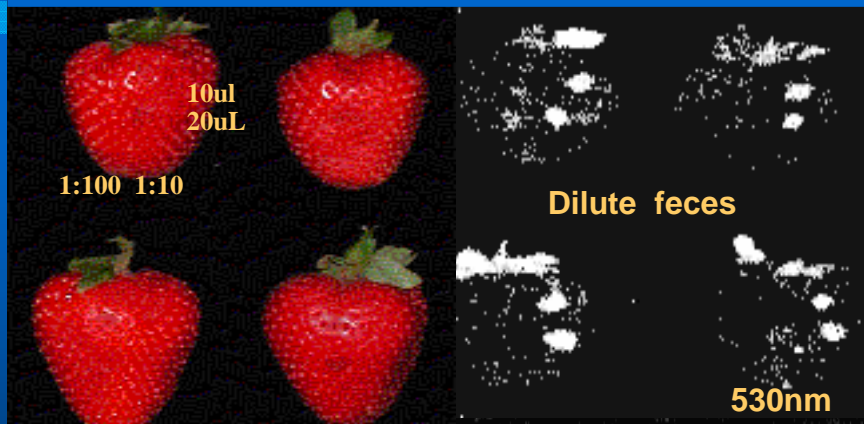Spectral Characteristics
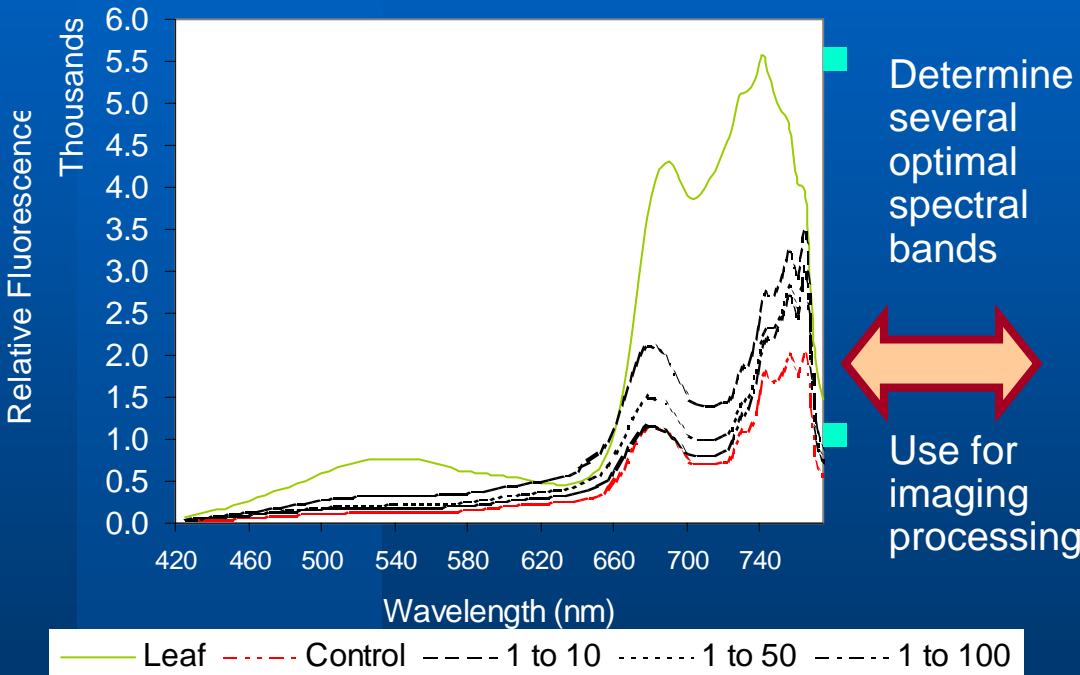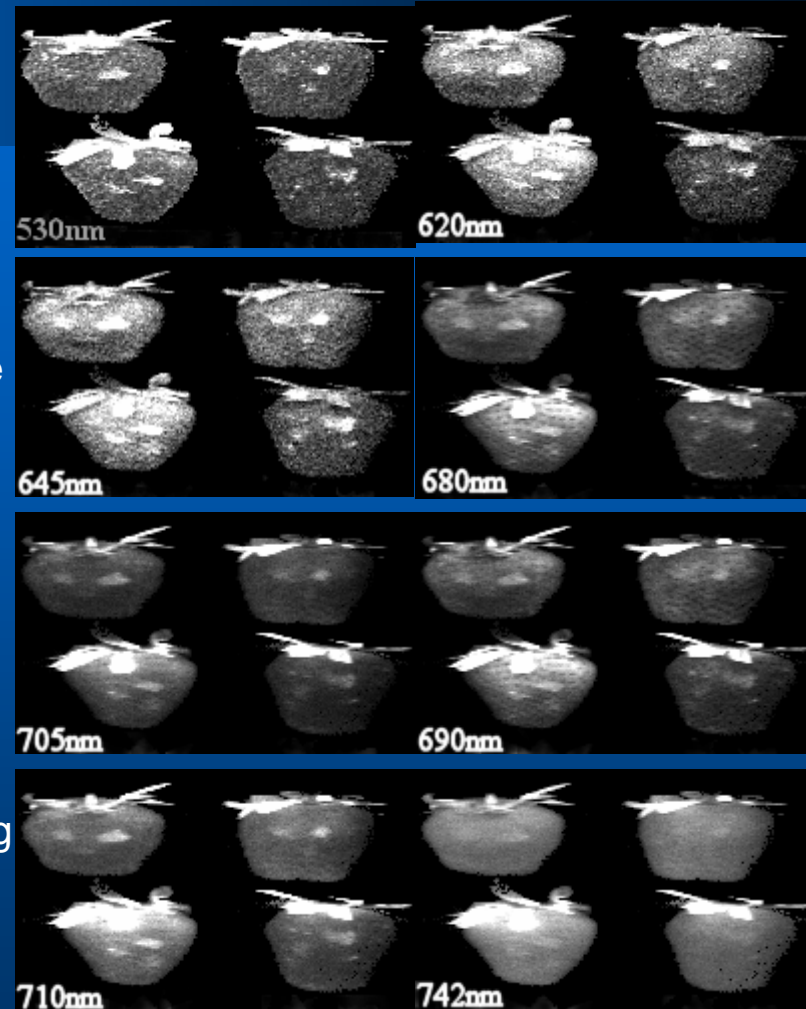
These images correspond to fluorescence emission maxima and minima in the natural spectral curve

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Results

Determine several optimal spectral bands

⬌

Use for imaging processing

Spectral Characteristics

- These images correspond to fluorescence emission maxima and minima in the natural spectral curve

Results
Fluorescence Images

Pure Feces

530nm

Dilute feces

530nm

Decayed

510nm

10ul
20uL

1:100 1:10

Digital color images

Hyperspectral images

Average Spectra

Relative Fluorescence

Wavelength (nm)

— Fecal — Normal — Decayed

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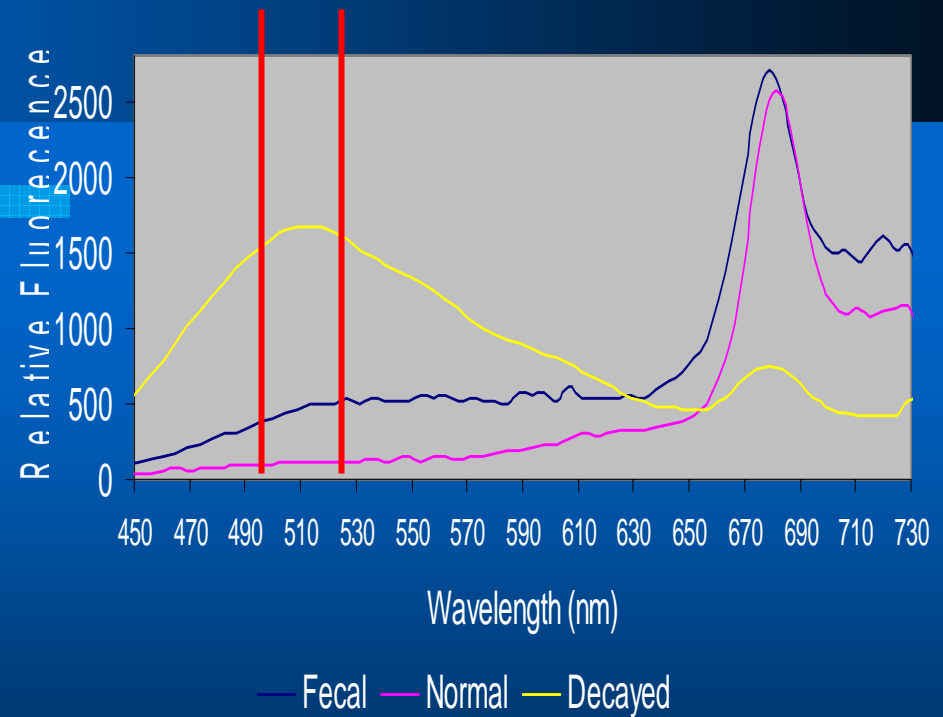
Results

Hyperspectral Imaging Processing Techniques
Band Ratio -- 2
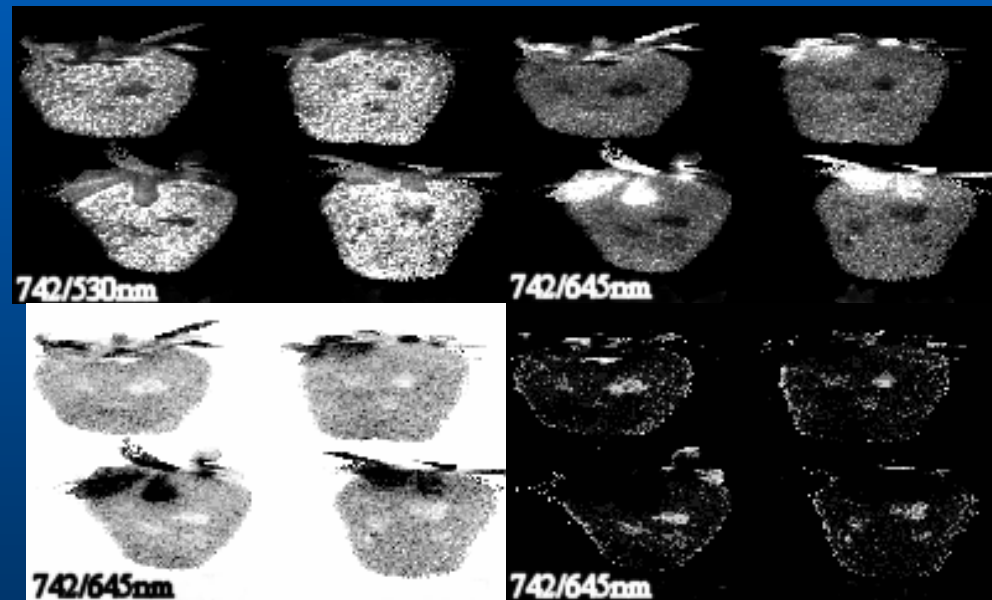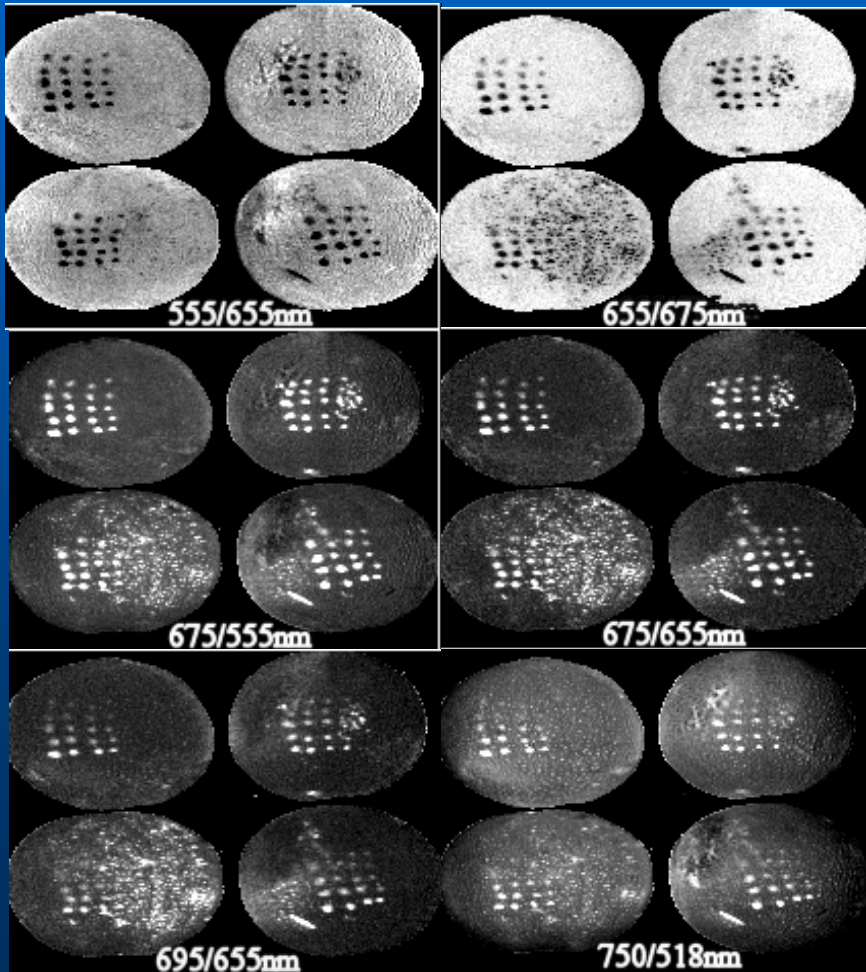
Results

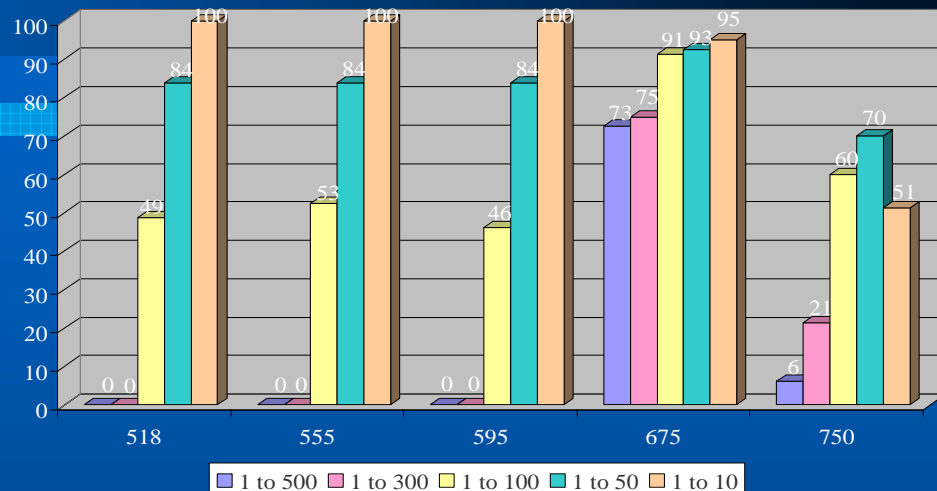## Hyperspectral Imaging Processing Techniques
Unsupervised Classification ISODATA -- 3

555/655nm   655/675nm   675/555nm

675/655nm   695/655nm   750/518nm

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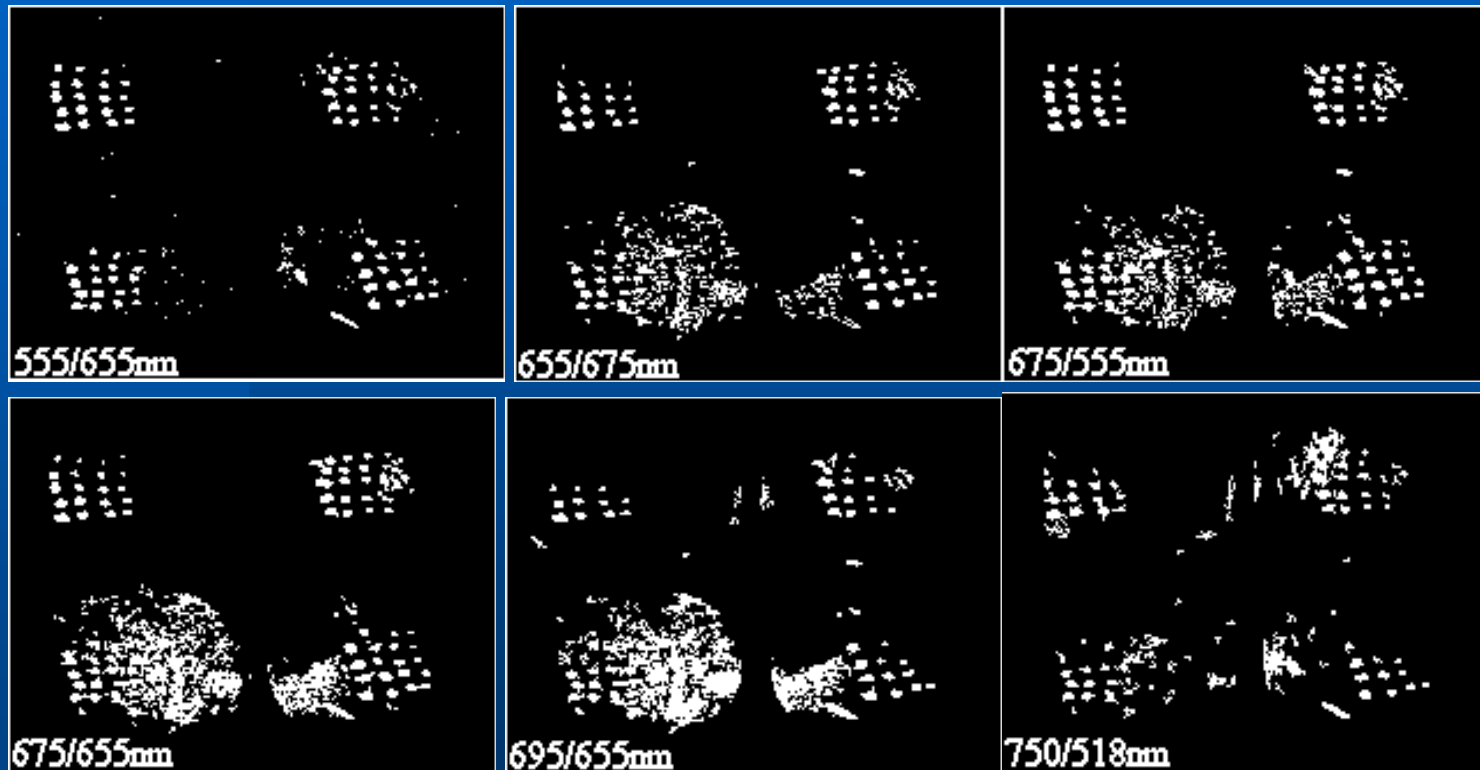
Results
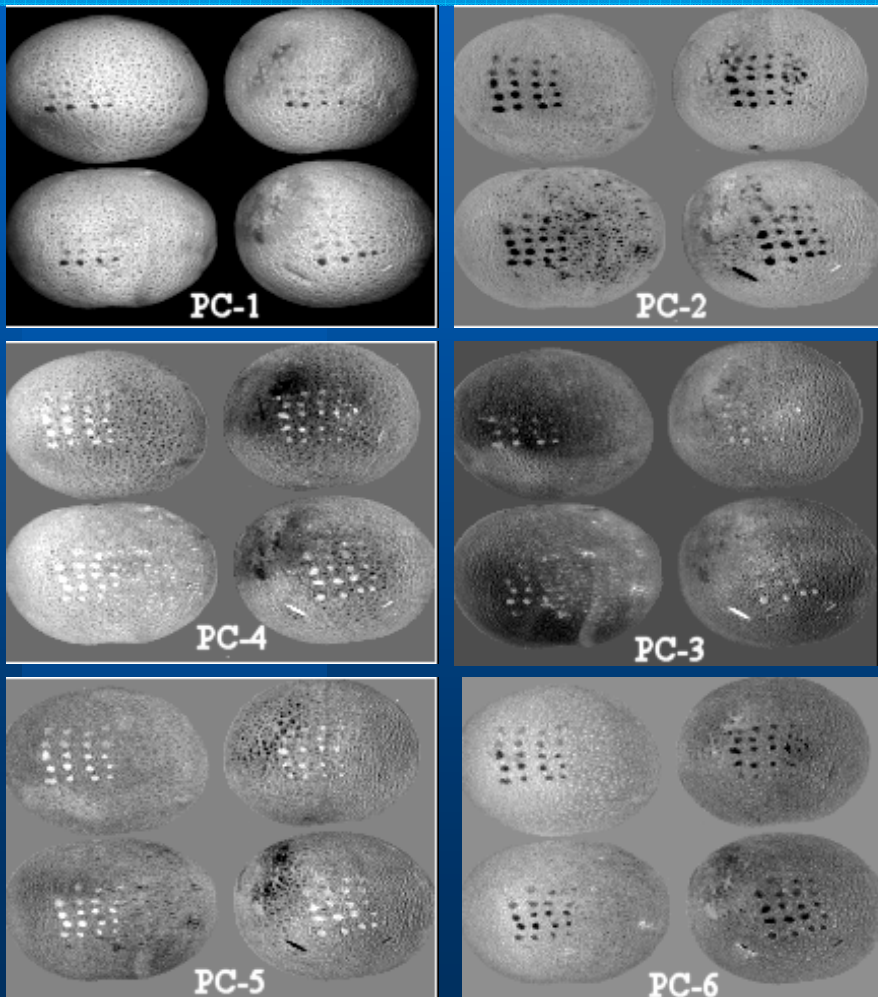## Detection Rates

Ratio Band
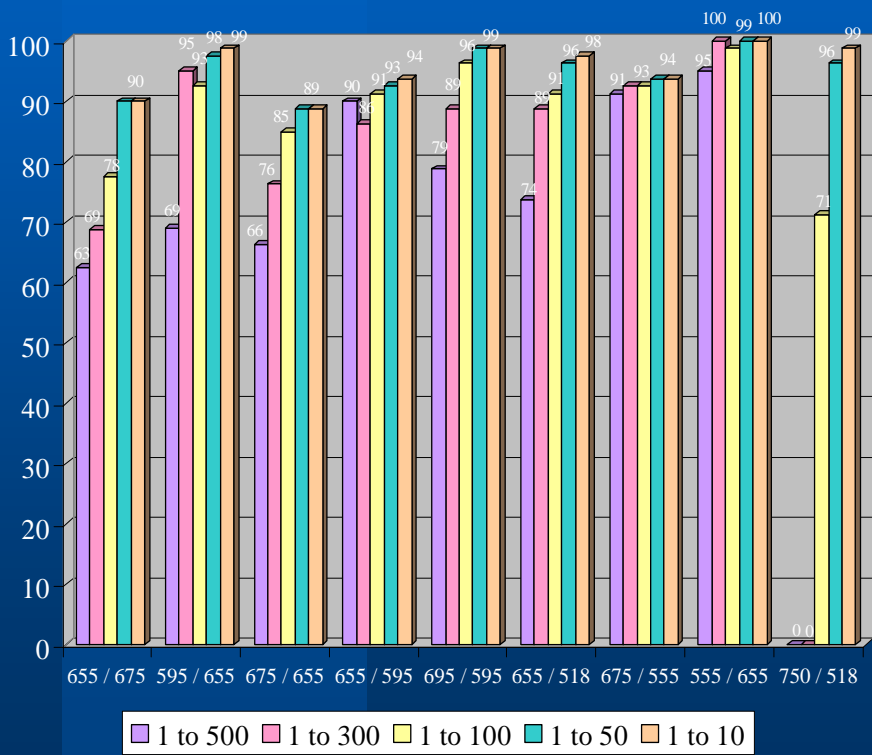
Single Band

Unsupervised Classification "ISODATA"
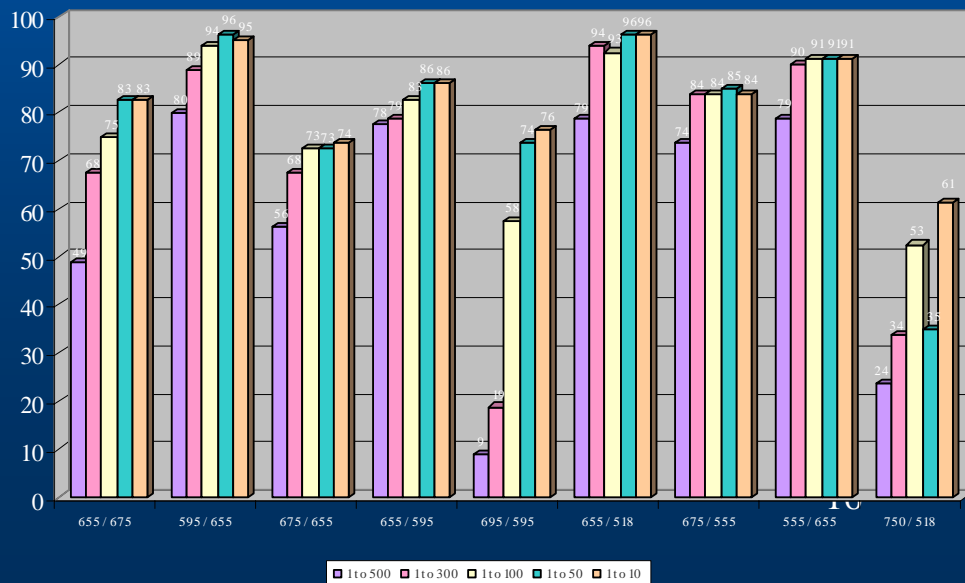
Results
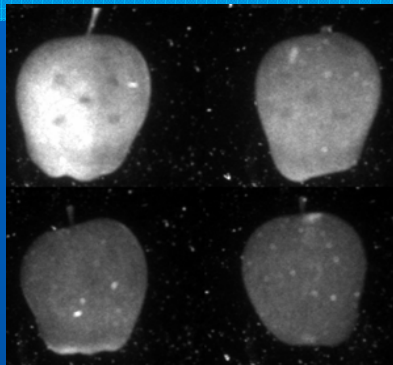
Hyperspectral Imaging Processing Techniques
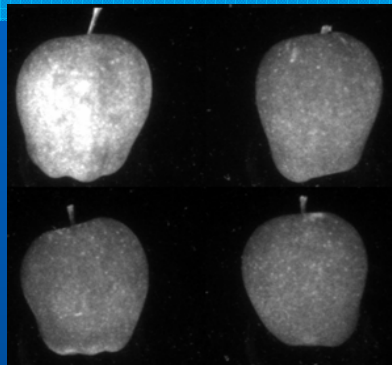### Principal Component Analysis -- 4
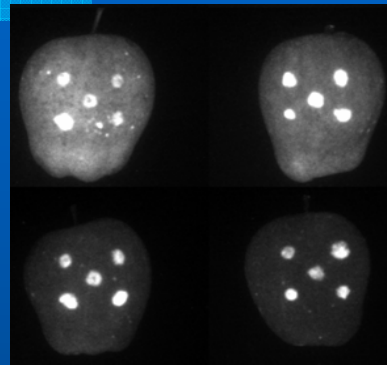

Weighing Coefficient (Eigenvectors)
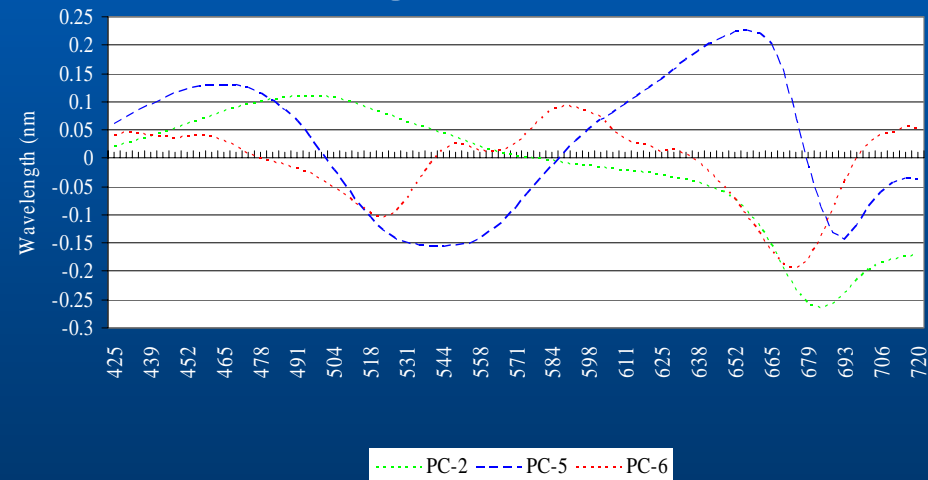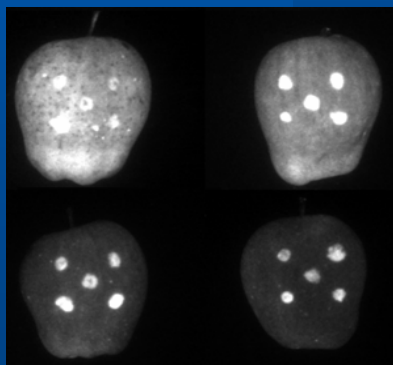
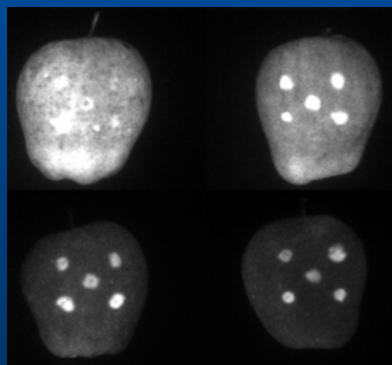# Apple Research

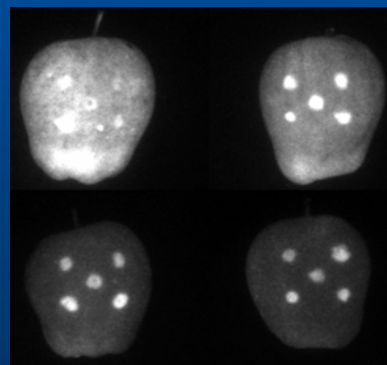a) F450-40 nm FWHM

b) F550-40 nm FWHM
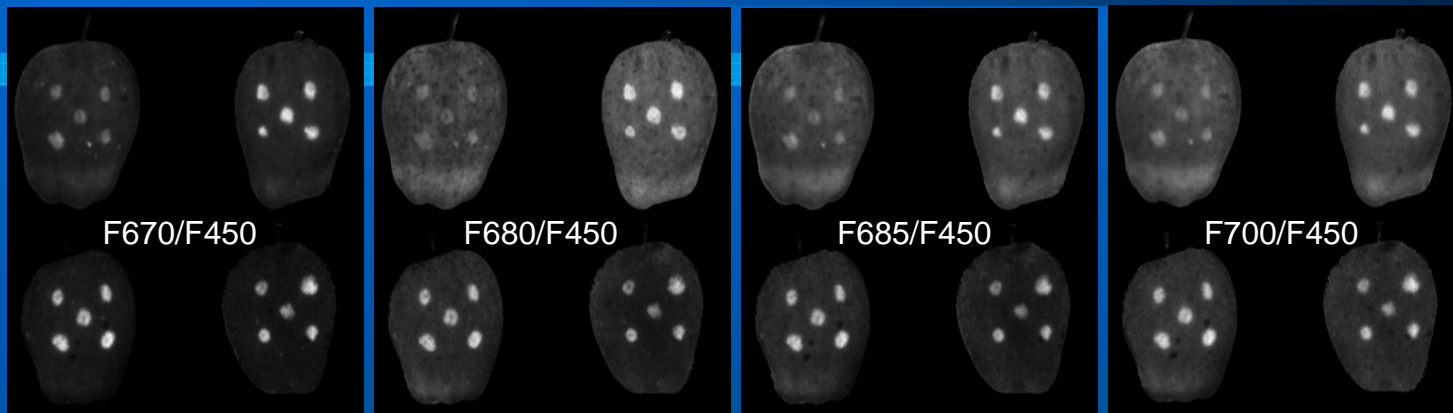
c) F670-10 nm FWHM

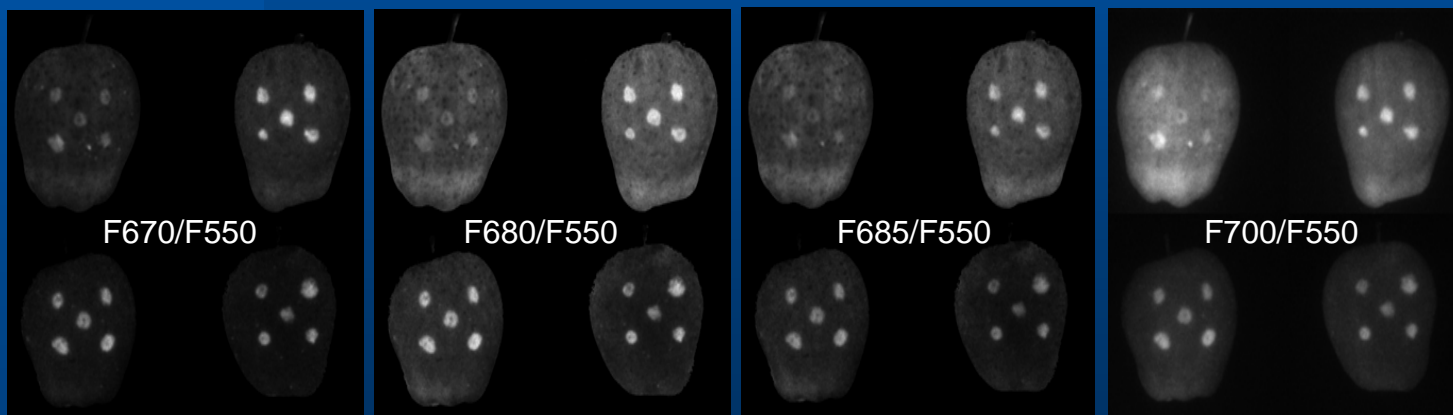d) F680-22 nm FWHM

e) F685-10 nm FWHM

f) F700-40 nm FWHM

Steady-state fluorescence images of the shaded (top two apples) and sun-exposed (bottom two) sides of apples with cow feces contamination spots acquired by multispectral fluorescecne imaging system at F450, F550, F670, F680, F685, and F700.
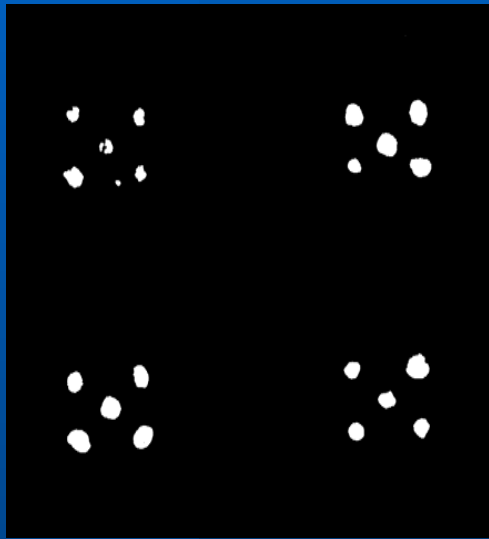
Kim, et al.

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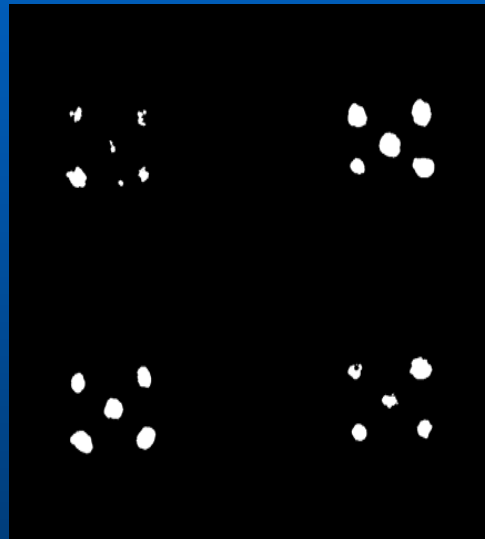F670/F450 F680/F450 F685/F450 F700/F450

a) Red Bands / Blue Band

F670/F550 F680/F550 F685/F550 F700/F550

b) Red Bands / Green Band

Kim, et al.

Detected

a) F670/F450   b) F670/F550   c) F680/F450

Kim, et al.
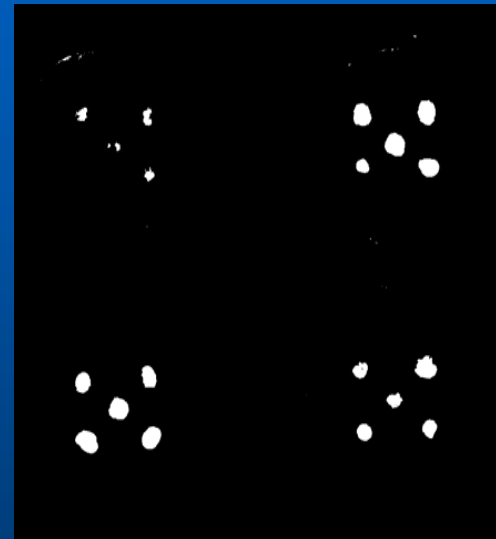
Use of On-line Multispectral System

Machine Intelligence

Labor Intensive

MERLIN® vision system for fruit inspection
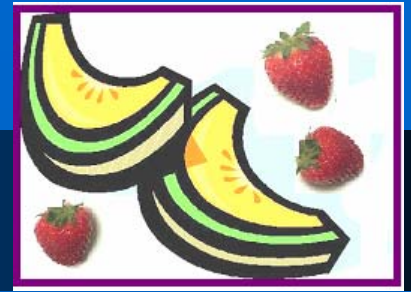
Summary

- *Single band images positively show contamination, detection rates are improved using ratio images.*

- *Unsupervised classification images can remove unwanted areas, and isolate treated areas.*

- *PCA showed that the first six principal component (PC) images exhibited useful results for contamination detection and redundancy reduction.*
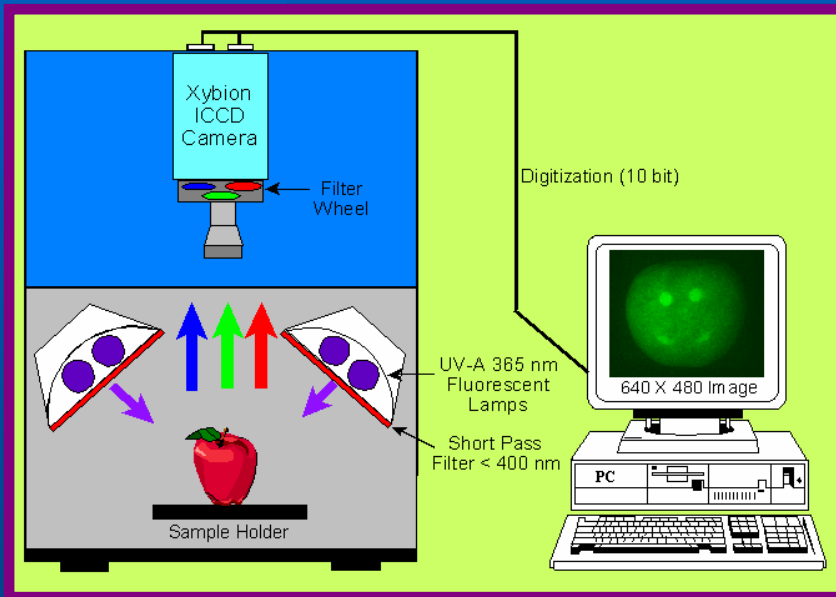
22
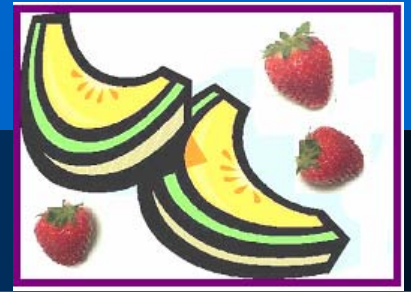
On-going Work

- **Continue to develop the multispectral imaging analysis;**

- **Classification algorithms for detection of feces and anomalies;**

- **Statistical validations;**

- **Journal publications.**

Instrument

Multispectral Fluorescence Imaging System (MFIS)

Schematic diagram of the MFIS

- **The MIS consists of:**
  - **Intensified-CCD (ICCD) camera with a six position filter wheel (480 H and 640 V pixel resolution).**
  - **10-bit A/D frame-grabber.**
  - **UV-A fluorescent lamp assemblies.**
  - **Four short-pass filters.**

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THANK YOU