Hyperspectral imaging analysis to evaluate Freshness of Pleurotus
利用高光譜影像技術檢測杏鮑菇新鮮度

Chao-Cheng Wu

Department of Electrical Engineering
Taipei Tech

Outline

- Motivations
- Hyperspectral Sensors
- Methodology
- Experimental Results
- Conclusions

Motivations (1/2)

- Pleurotus eryngii, known as king oyster mushroom, is one of the most popular food in Taiwan.
- The freshness of Pleurotus eryngii plays an important role in its values.
- Currently, the common way to evaluate its freshness is mainly based on human senses, such as its look, smell, etc.
- The results could be very subjective and time-consuming to inspect a huge number of Pleurotus eryngii at a time, which make both of them difficult to use in commercial market.

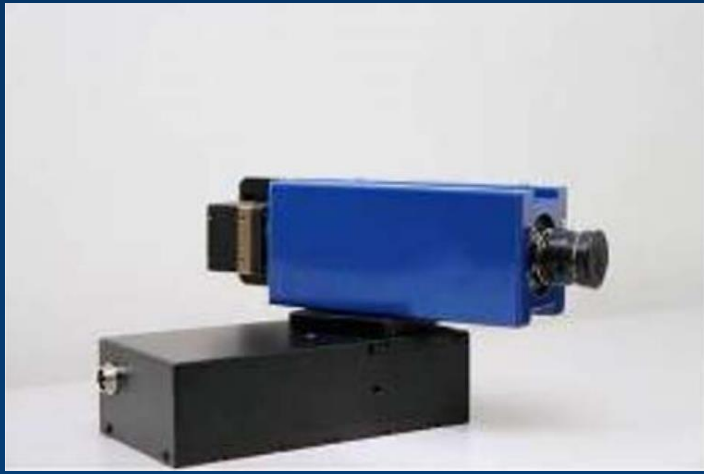
Motivations (2/2)

- Hyperspectral imaging has recently emerged as a powerful tool for non-destructive food analysis.
- An imaging-based non-destructive method was proposed to determine the freshness of king oyster mushrooms (Pleurotus eryngii).
- The aim is to find characteristic spectra and bands for determination of freshness level.

Hyperspectral Sensors (1/4)

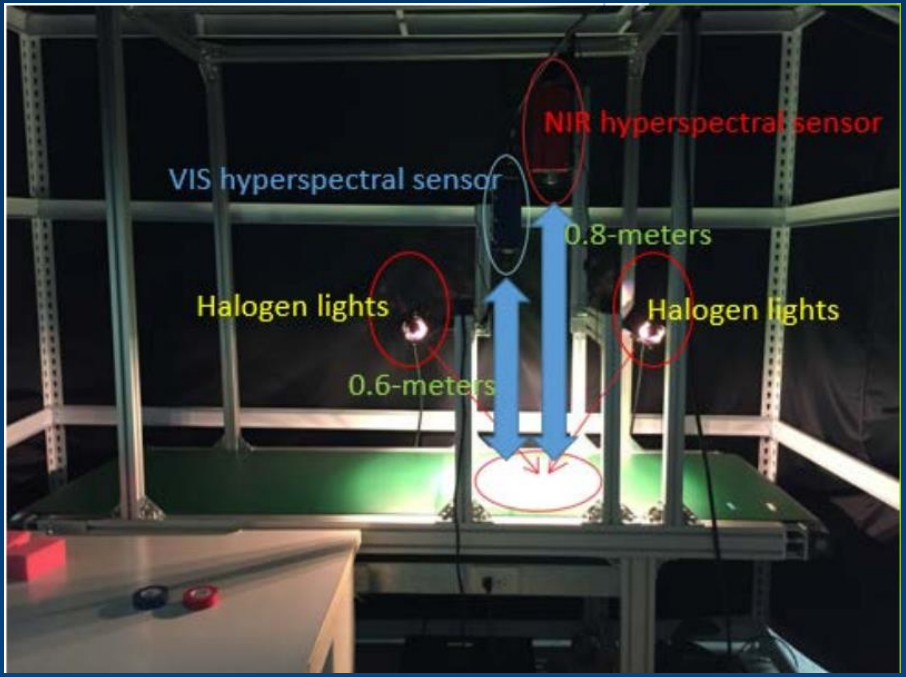
- GaiaField hyperspectral system is ultraportable imaging system and developed by Titan Electro-Optics Co., Ltd.
- The spectral resolution of GaiaField N17E-N3 is 3.4 nm
- The covered wavelength is 900-1700nm, and the number of band is 256 spectrum channels.

Hyperspectral Sensors (2/4)

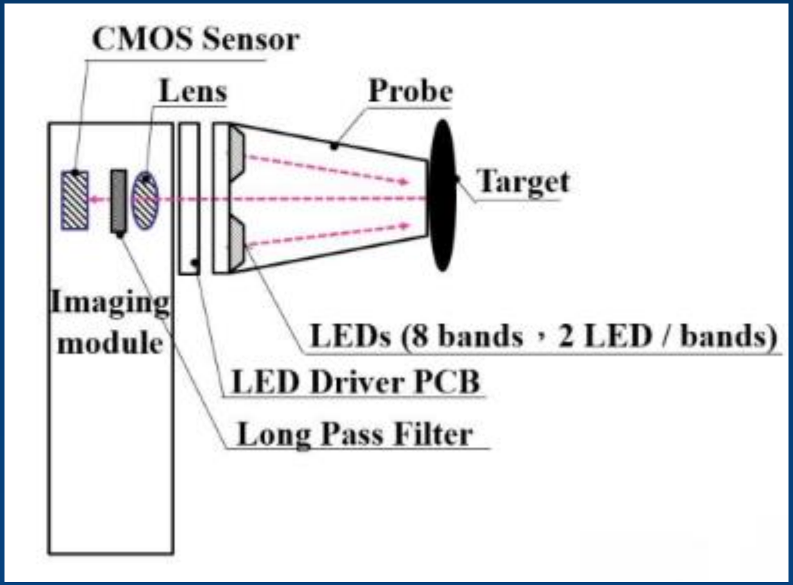


	Isuzu Optics-V10E-B1410CL	Isuzu Optics-N17E-InGaAs
Wavelength	400nm to 1000nm	900nm to 1700nm
Spectral Resolution	2.8 nm	1.5 nm
Number of Bands	214	512

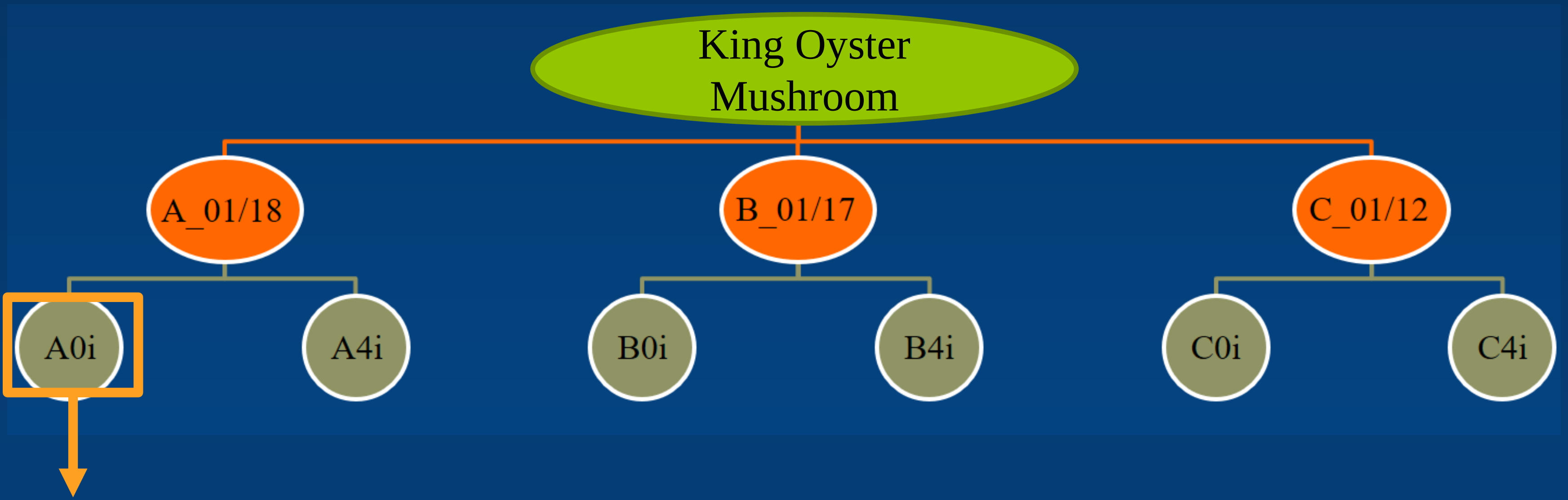
Hyperspectral Sensors (3/4)



Hyperspectral Sensors (4/4)



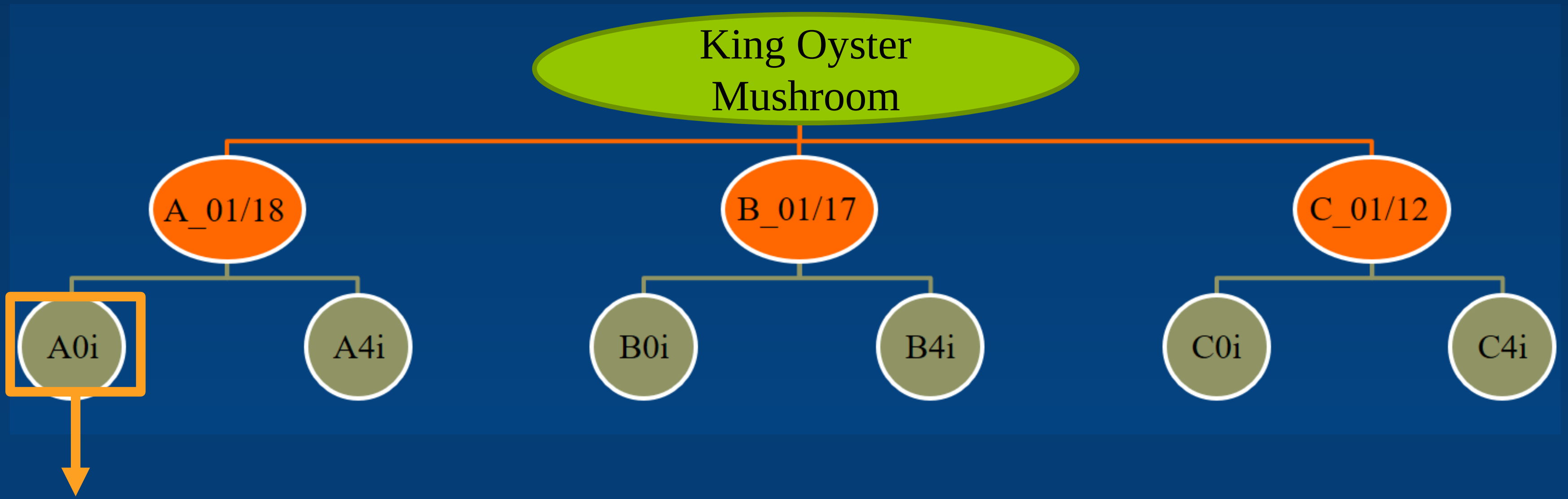
Methodology
Data Collection (1/5)



A0i

- Each mushroom could also be categorized into three classes based on their size.
  - The biggest one was labelled as **A class**
  - The medium one was labelled as **B class**
  - The smallest one was labelled as **C class**

Methodology
Data Collection (2/5)



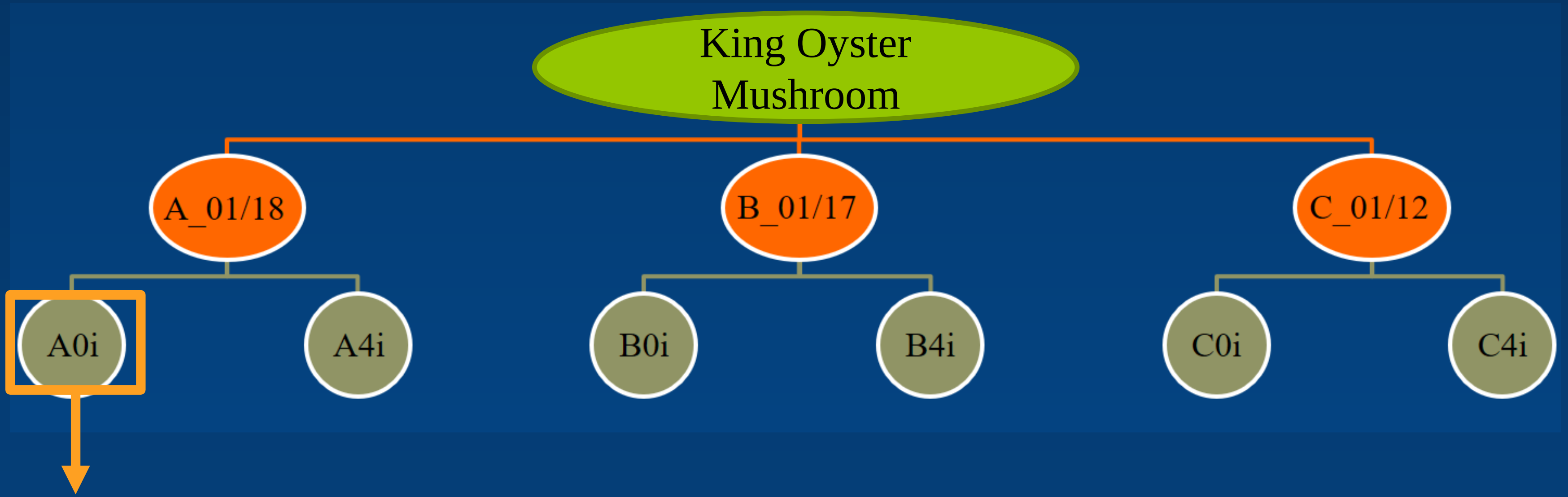
A0i

- The template resolution was 7 days
- Five times were collected, which are 0-, 7-, 14-, 21-, and 27-day

A4i

- The template resolution was 30 minutes after storage for 4 weeks.

Methodology
Data Collection (3/5)



A0i

- Two types of storage environments were simulated
  - The first one was stored at room temperature labeled as ‘**n**’
  - The other type was kept in the refrigerator labeled as ‘**i**’

Methodology
Data Collection (4/5)

The collection date of all experimental mushrooms

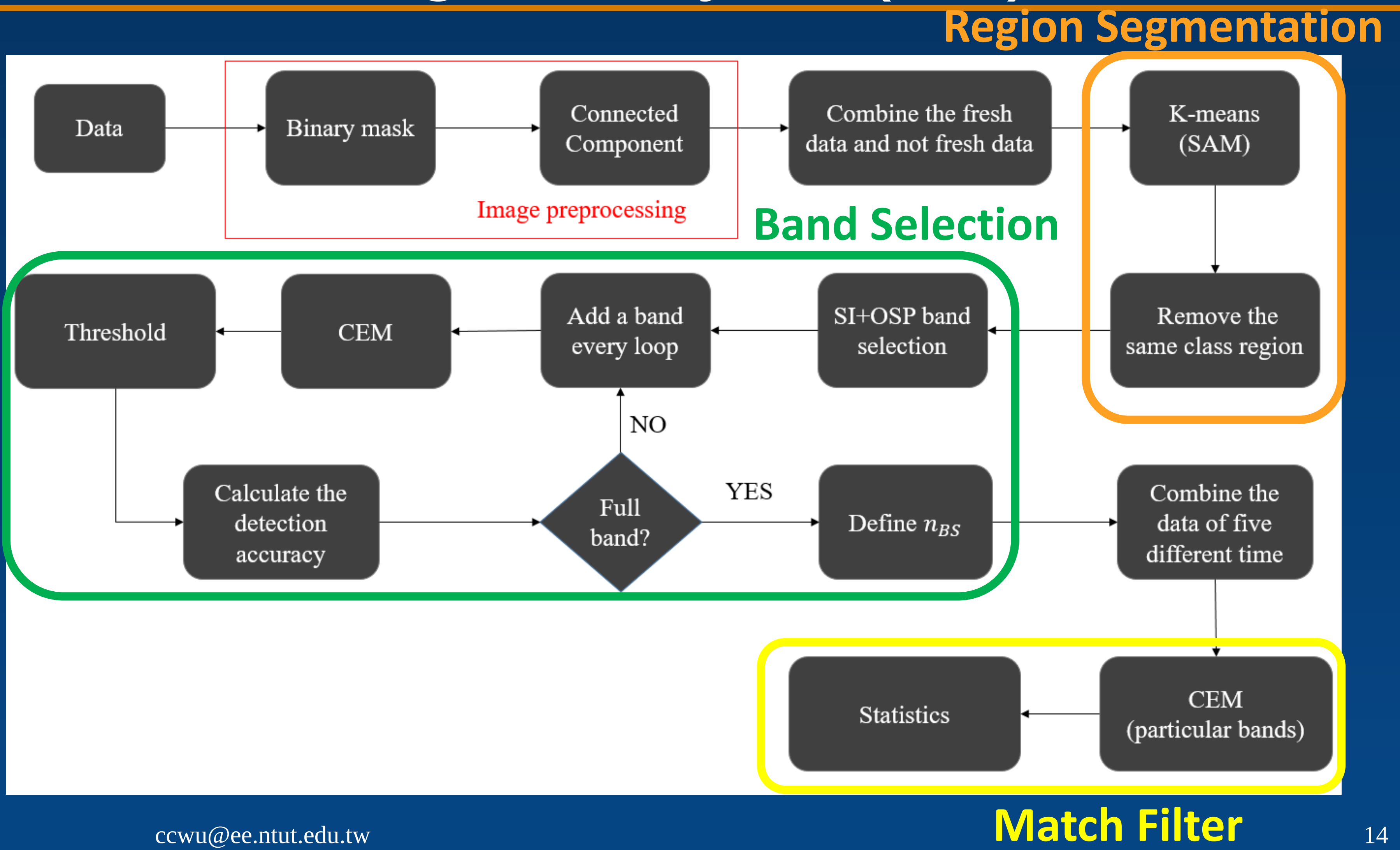
Label	Scan Date	Storage Duration
A0i A0n B0i B0n C0i Con	2018/1/18	1 day
	2018/1/25	7 days
	2018/2/1	14 days
	2018/2/8	21 days
	2018/2/14	27 days
A4i A4n B4i B4n C4i C4n	2018/2/14 09:30	27 days
	2018/2/14 10:00	27 days
	2018/2/14 10:30	27 days
	2018/2/14 11:00	27 days
	2018/2/14 11:30	27 days

Methodology
Data Collection (5/5)

Room Temperature

Refrigerator

Methodology
Image Analysis (1/4)



Methodology
Image Analysis (2/4)

- SAM-Based *k*-means Clustering was applied for the characteristic spectra related to freshness
- The SAM-based *k*-means cluster took advantage of the Spectral Angel Mapper (SAM) as similarity measurement function
- SAM measurement could help to reduce the effects of light scattered from the three dimensional shape.

$$\mathrm{SAM}(S_i, S_j) = \cos^{-1}\left(\sum_{l=1}^{L} S_{il}\, S_{jl} \;/\; \left[\sum_{l=1}^{L} S_{il}^2\right]^{1/2} \left[\sum_{l=1}^{L} S_{jl}^2\right]^{1/2}\right)$$

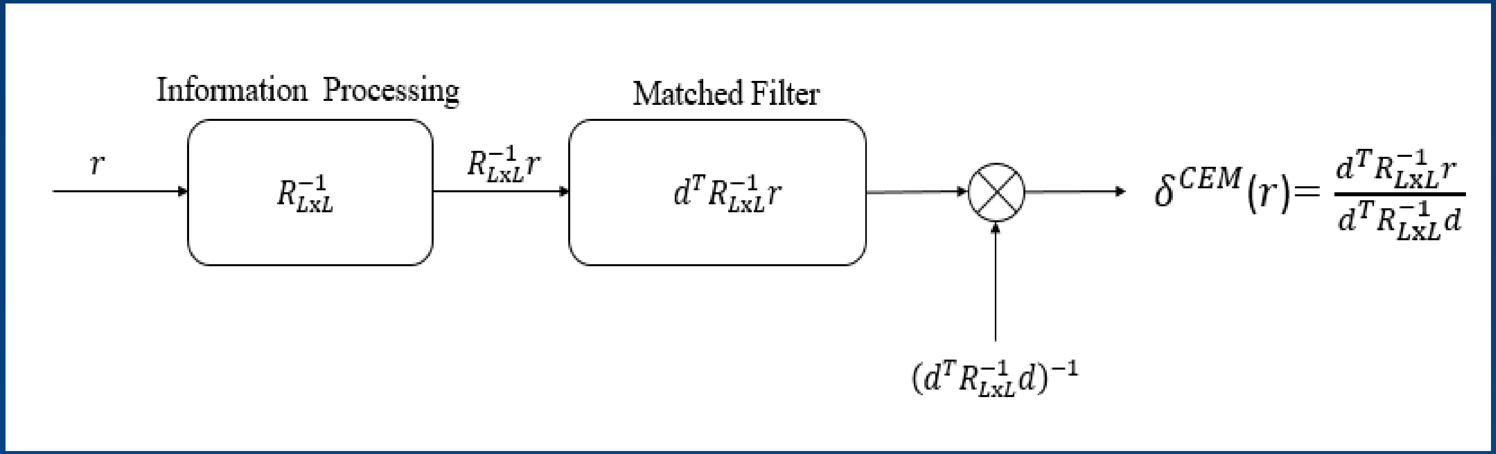
Methodology
Image Analysis (3/4)

- The Orthogonal Subspace Projection(OSP)-based band selection was applied for band selection to determine appropriate bands.
- The idea of OSP-based band selection is to annihilate information of the selected bands before selecting a new band.
- The initial band play a key role, and the separability index (SI) was applied to determine the initial band.

$$SI_i = \frac{\Delta_{inter,i}}{\Delta_{intra,i}} = \frac{|R_{mean,1,i} - R_{mean,2,i}|}{1.96 \text{ x } (\sigma_{1,i} + \sigma_{2,i})}$$

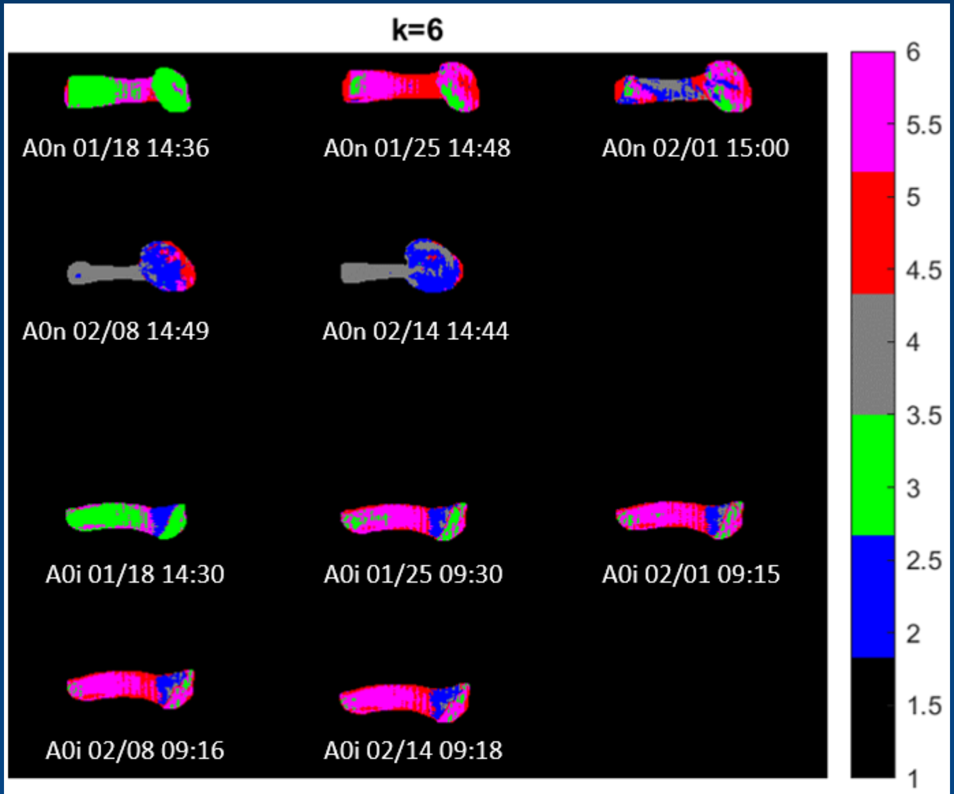
Methodology
Image Analysis (4/4)

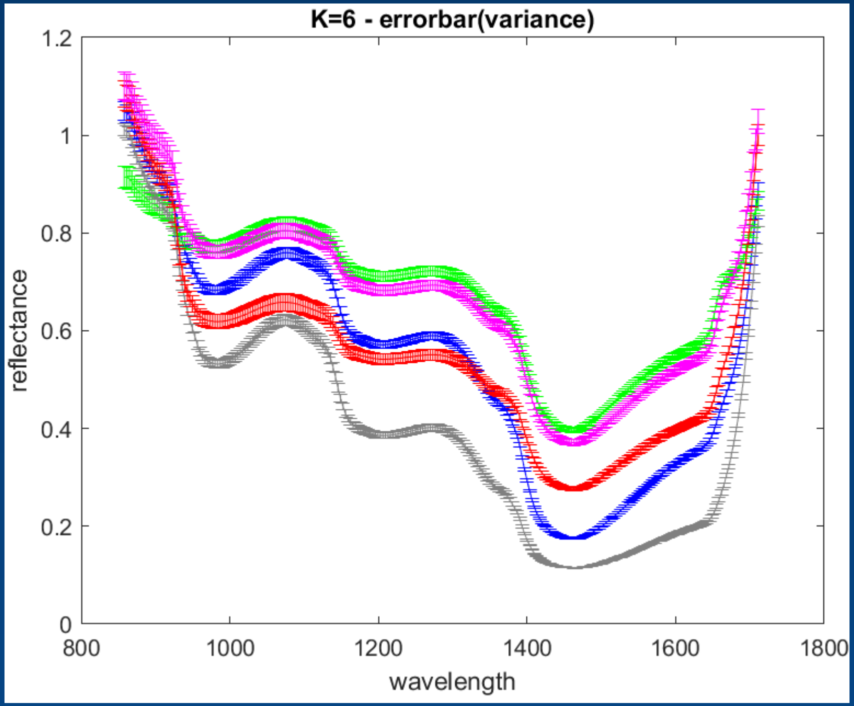
- Constrained energy minimization (CEM) detection algorithm was used to determine the freshness level.
- CEM is a FIR filter derived from linearly constrained minimum variance (LCMV) detector.



Experimental Results (1/8)

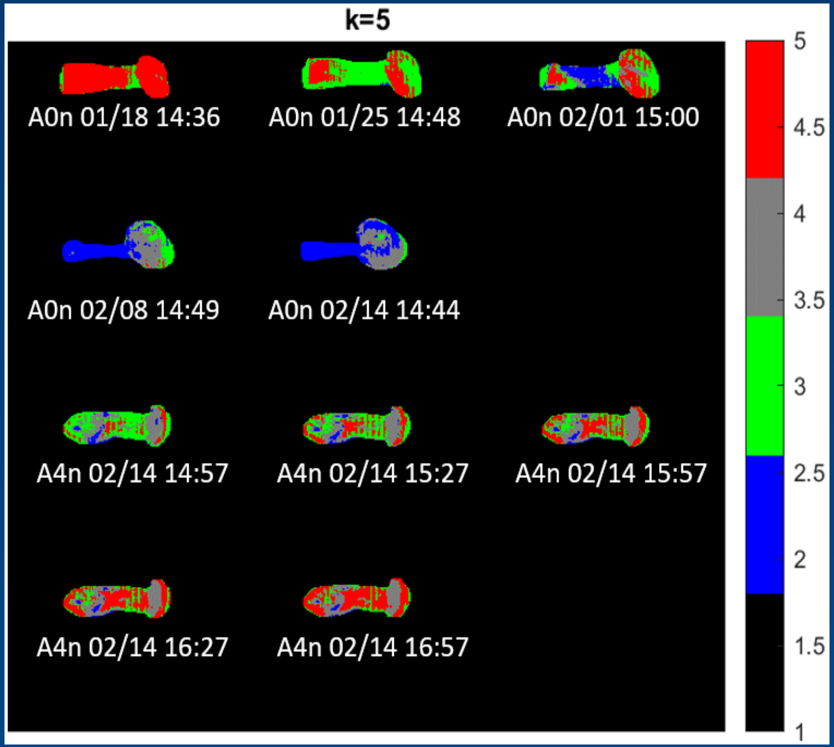
5 classes were segmented by SAM-Based k-means Clustering on samples of A0n and A0i

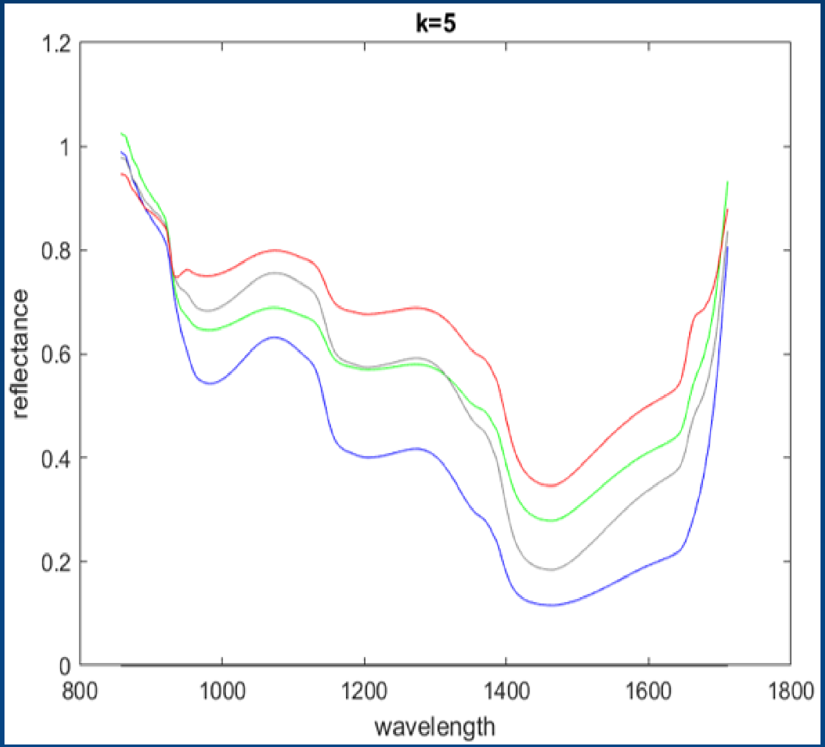




Experimental Results (2/8)

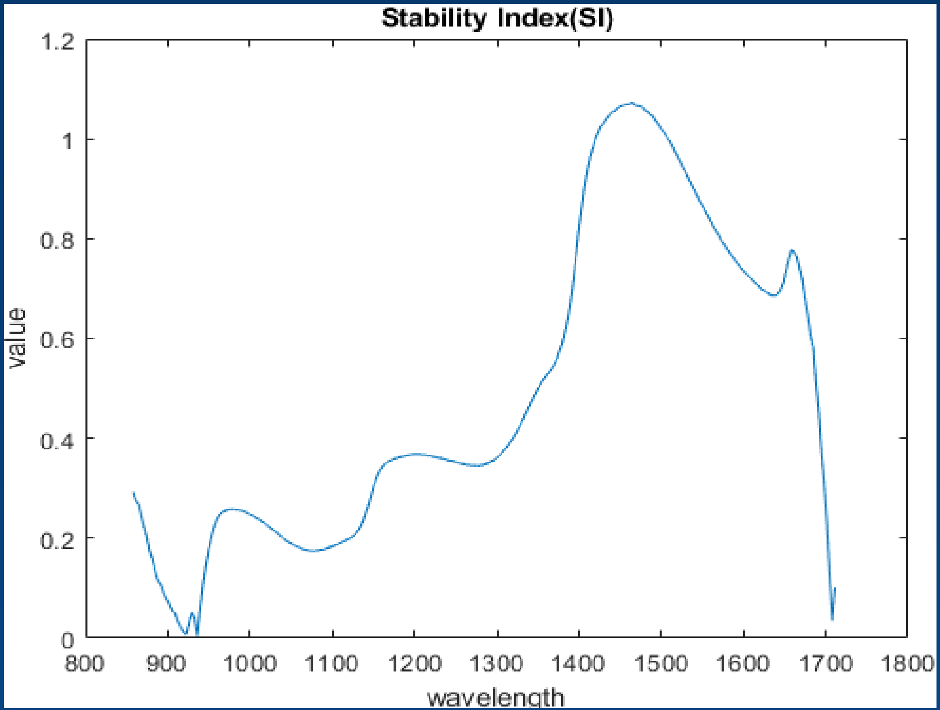
4 classes were segmented by SAM-Based k-means Clustering on samples of A4n and A4i



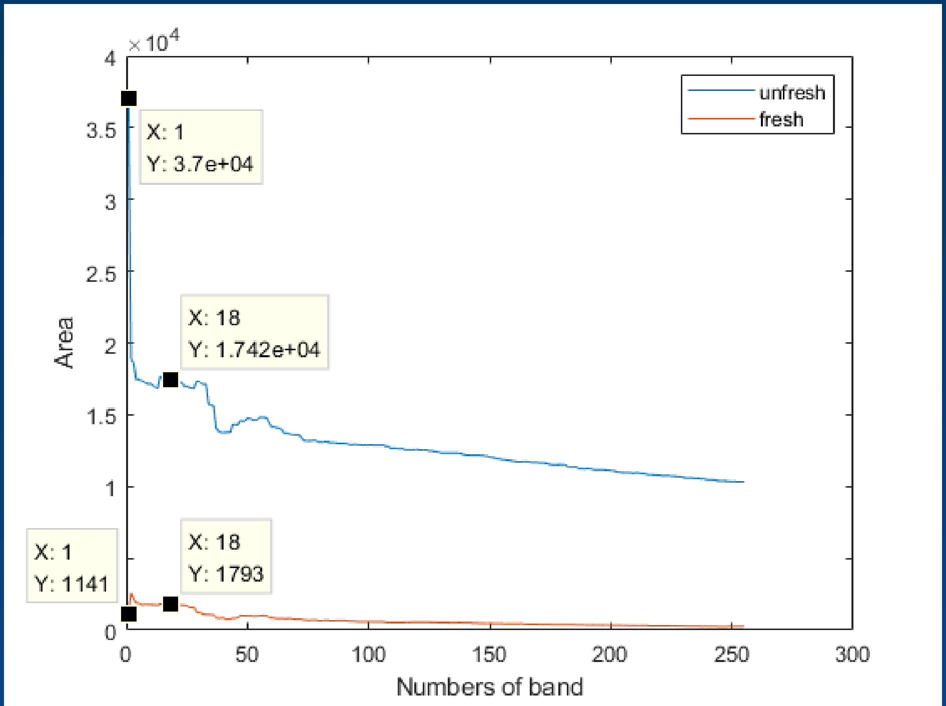


Experimental Results (3/8)

SI score for each spectral band

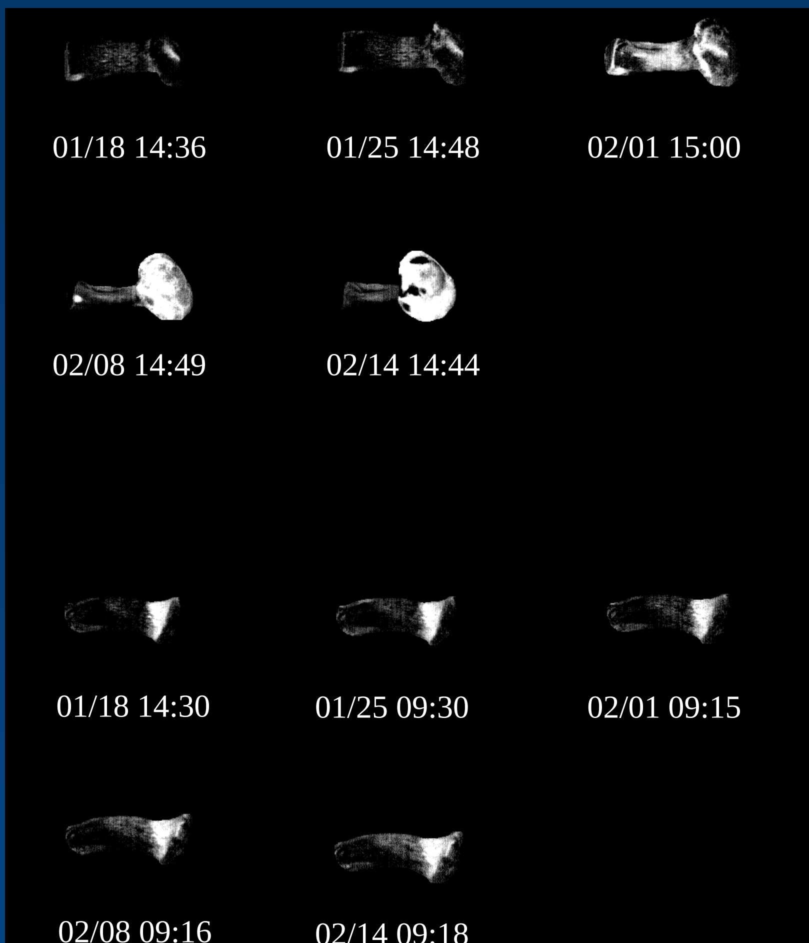


The area detected via CEM with different numbers of OSP-based selected bands



Experimental Results (4/8)

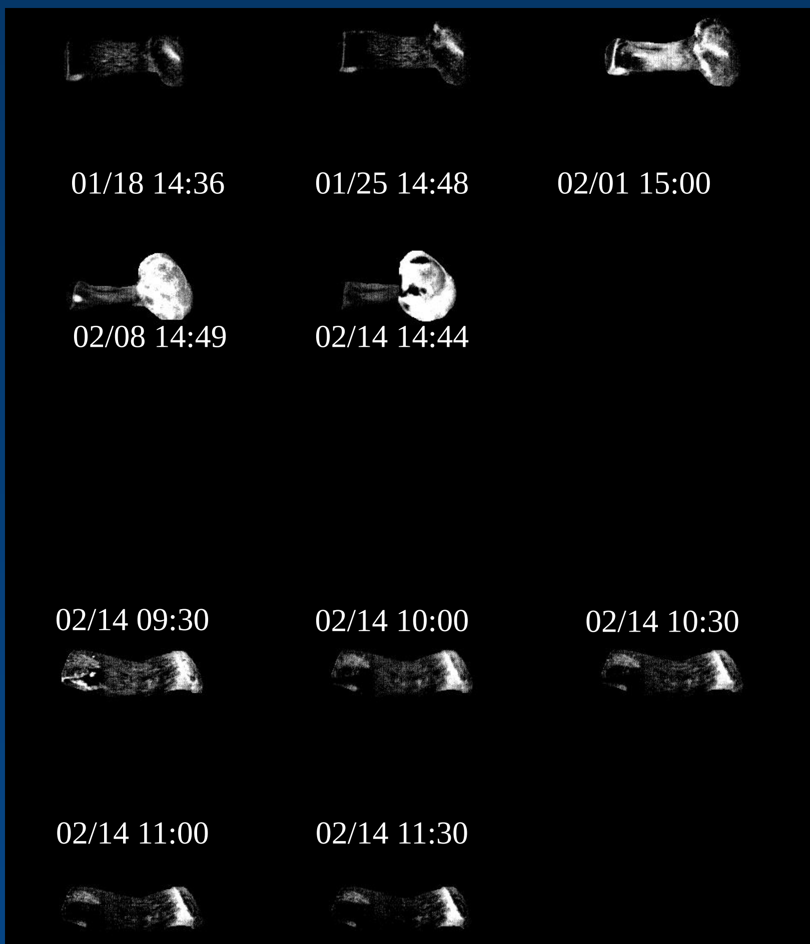
CEM Results of A0n and A0i



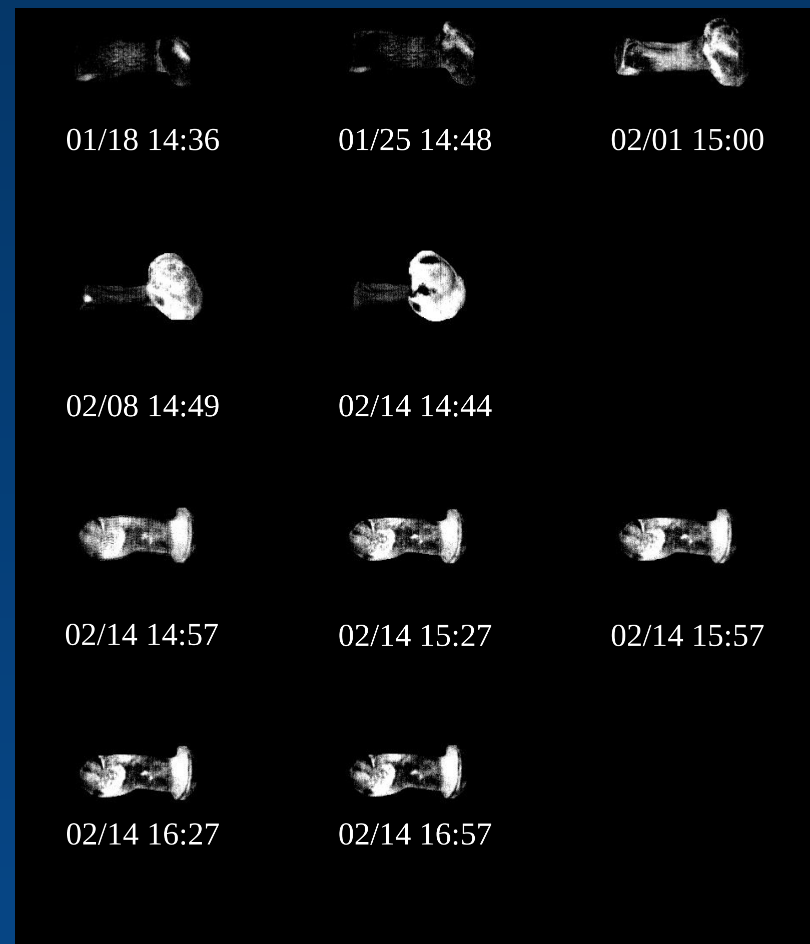
CEM results of two different A0n

Experimental Results (5/8)

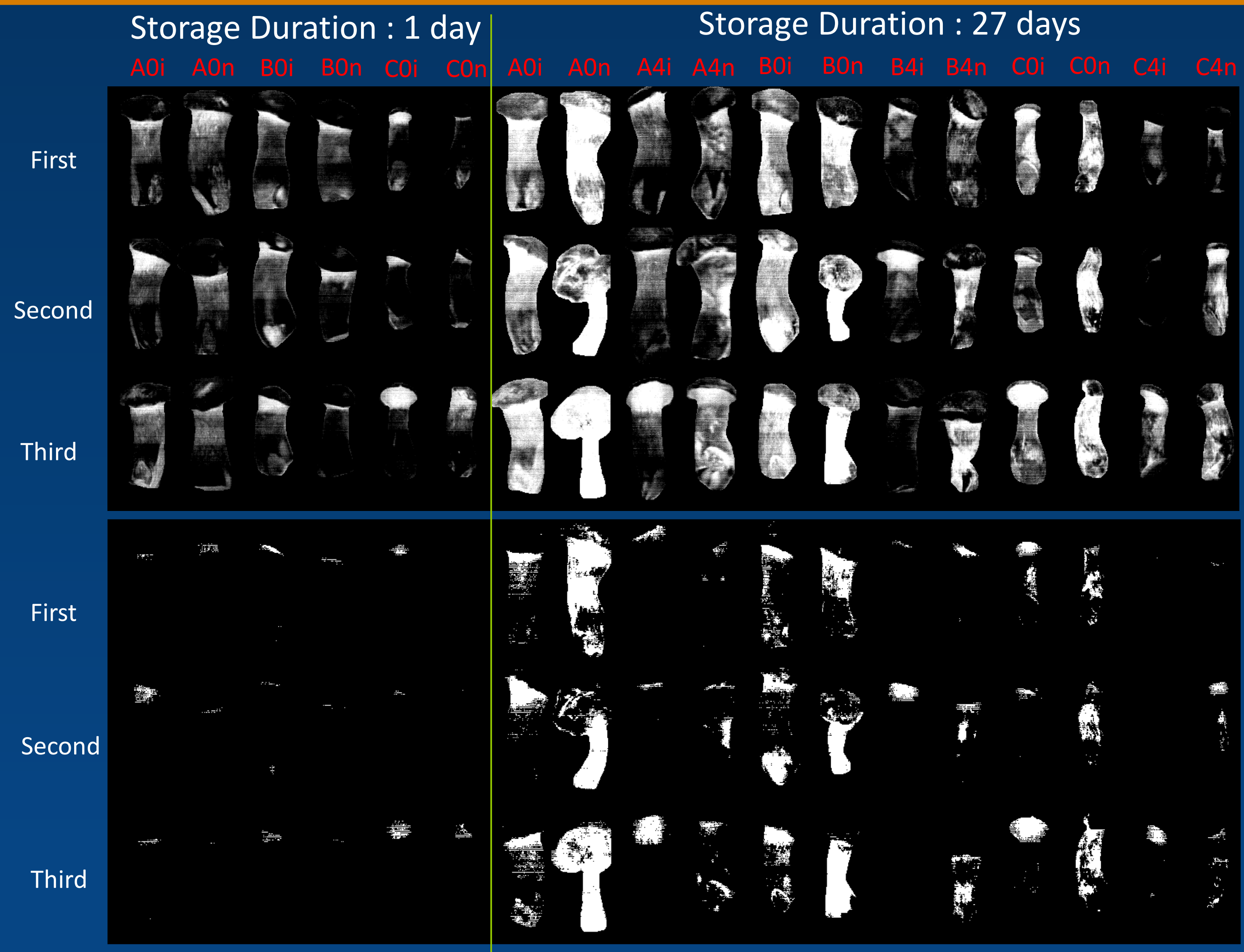
CEM Results of A0n and A0i



CEM Results of A0n and A0i



Experimental Results (6/8)

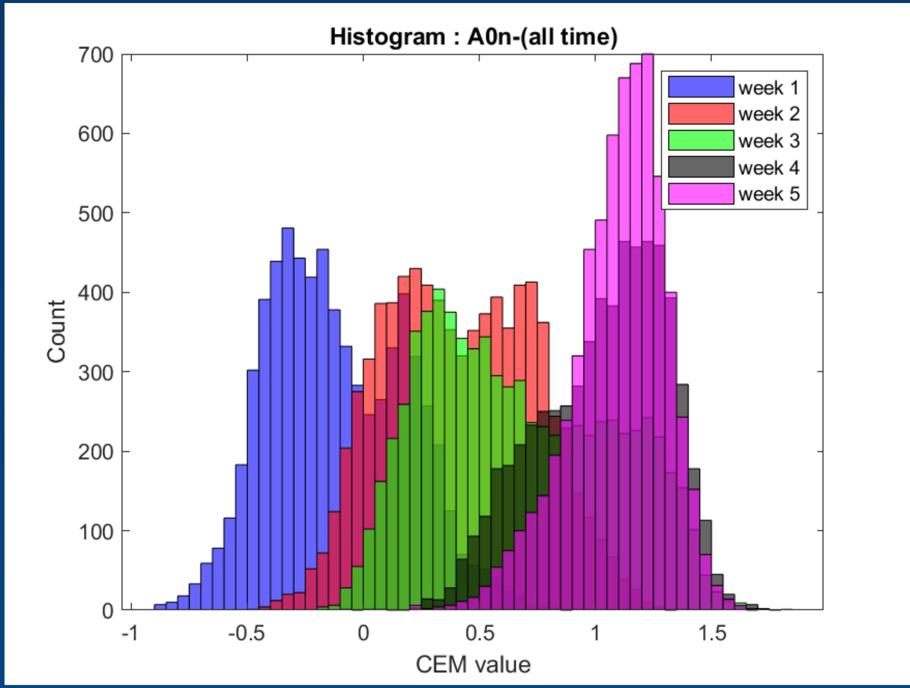


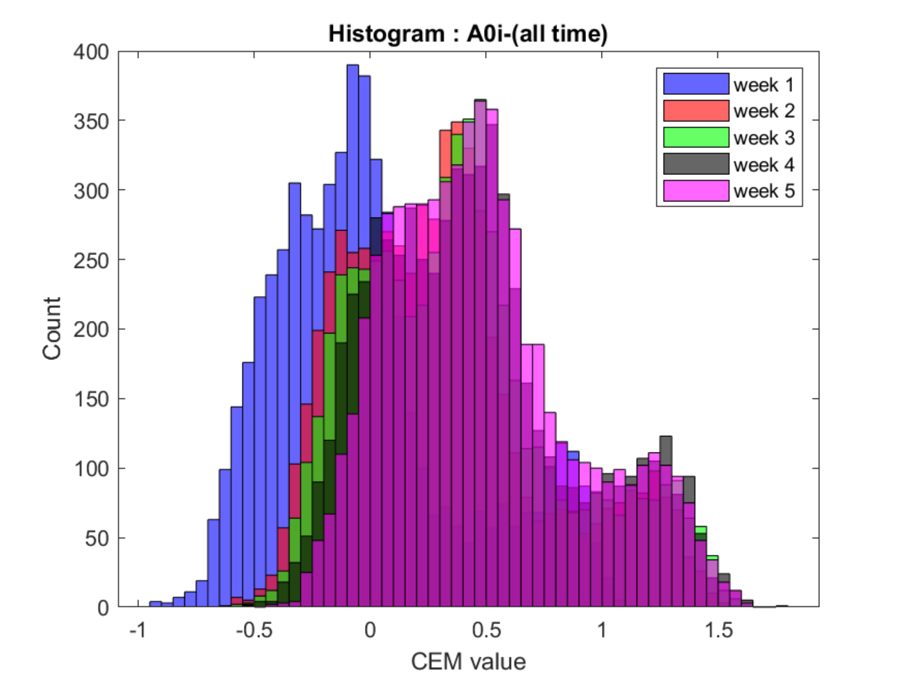
CEM Results based on two selected bands (1463nm、857.9nm)

Binary image

Experimental Results (7/8)

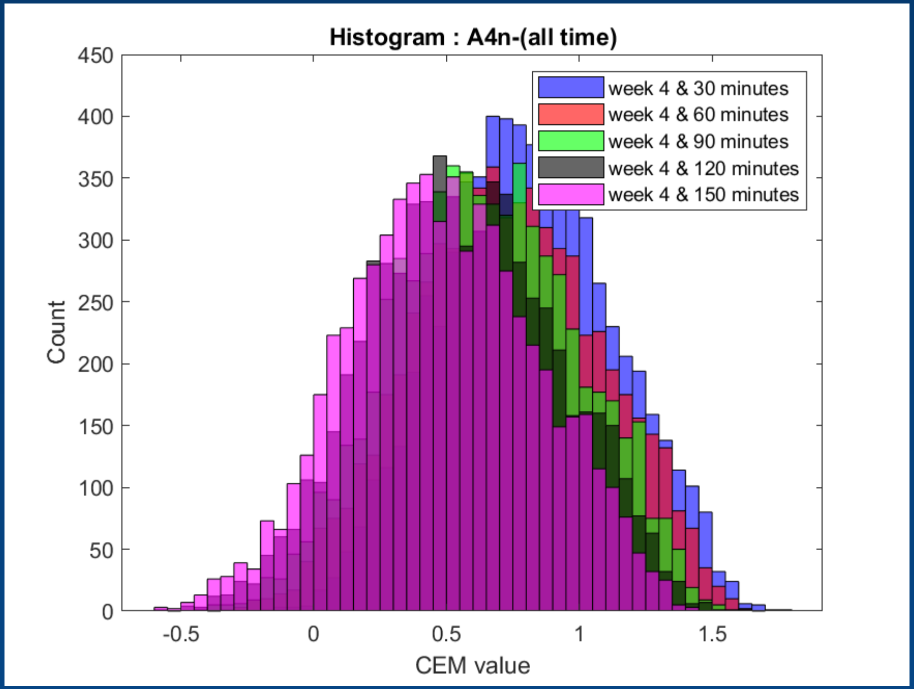
- Histogram of pixel values of CEM results could be utilized as an indicator of the storage duration.

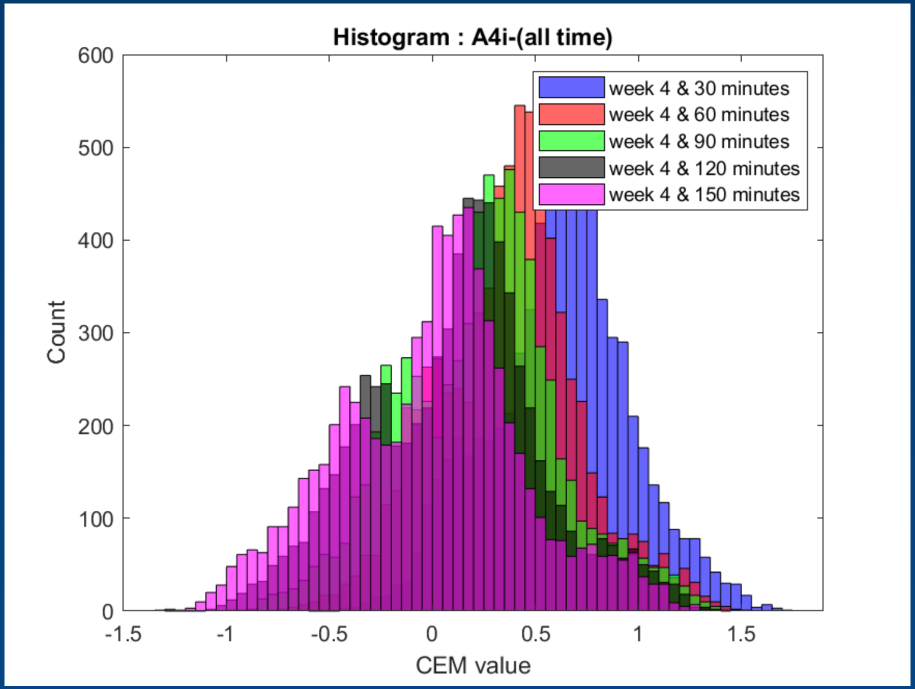




Experimental Results (8/8)

- Histogram of pixel values of CEM results on A4i and A4n was much more stable compared with the previous ones.





Conclusions

- A non-destructive method to determine freshness of *Pleurotus eryngii* based on analysis of characteristic spectra and bands.
- The SAM-based *k*-means clustering algorithm was applied to find the characteristic spectral signatures related to the fresh level.
- The OSP-based band selection was utilized to look for the characteristic bands, 1463 nm and 858 nm.
- The characteristic spectra and bands could be further demonstrated by the distribution of the CEM values.
- The future work could further develop an hand-held device to measure the freshness in real time.

Thanks for your attention.