The 15th International Workshop on Nondestructive Quality Evaluation of Agricultural, Livestock and Fishery Products

Spectral Sensing of Crop Growth Status in Greenhouses

Suming Chen

KC Tung, CY Tsai, IC Yang

schen@ntu.edu.tw

Dept. of Bio-Industrial Mechatronics Engineering

National Taiwan University

Taipei, Taiwan

November 19, 2019

NTU BIME

Background

- Population aging, low birth rate, migration from rural to urban → Labor Shortage

- Increasing demands of high quality and safe agricultural products

- AI and ICT technologies help to make changes
  → Smart Agriculture

Smart Agriculture

Artificial Intelligence (AI)

Information and Communication Technology (ICT)

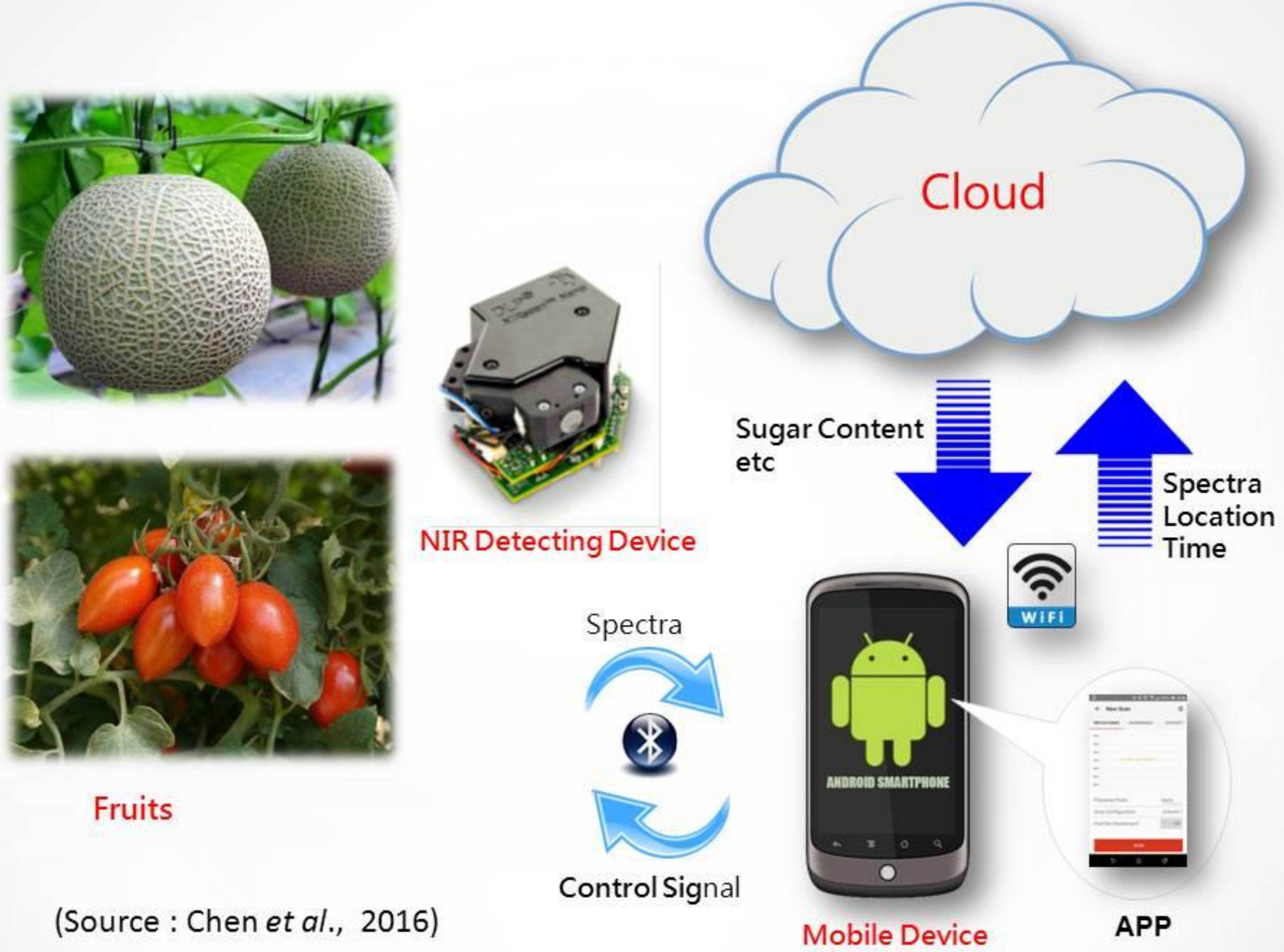
Cloud and Big Data

Internet of Things (IoT)

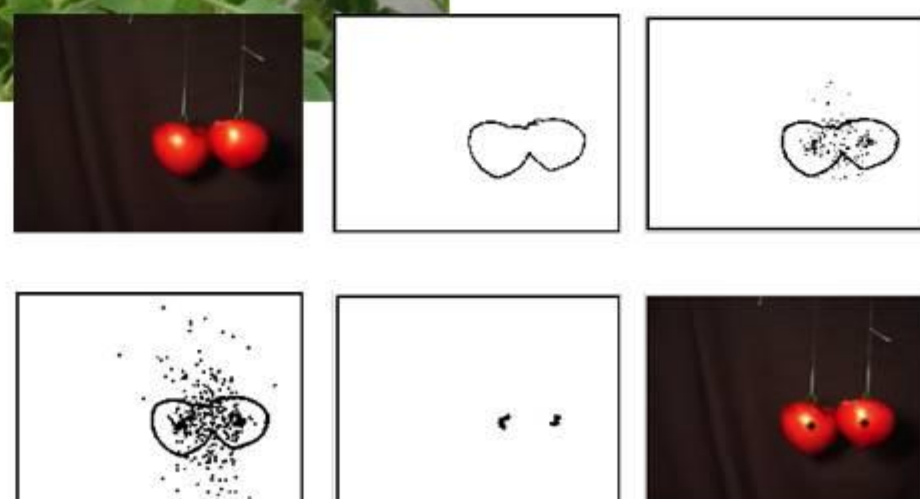
Precision Agriculture

Intelligent Agricultural Machinery

Bio-Robotics


Cloud
Sugar Content
etc
Spectra
Location
Time
NIR Detecting Device
Spectra
Control Signal
Fruits
WiFi
ANDROID SMARTPHONE
Mobile Device
APP
(Source : Chen *et al.*, 2016)

Tomato Picking Robot



(Source : Chen *et al.*, 2015)

- Precision Agriculture Approach
  - Site-specific cultivation
  - **Field Crops**
    - Plant Sensing Data
      - Remote Sensing by satellites
    - Position Information
      - Global Positioning System (GPS)
  - **Greenhouses ?**

Source: http://www.futuregov.asia

Problem Statements

- More and more crops such as vegetables and ornamental plants are grown in greenhouses.
- Growth status monitoring of these greenhouse crops is equally important as that for field-grown crops.
- Consequently, ground-based multi-spectral remote imaging and plant-oriented remote-sensing algorithms based on monitoring of plant physiological status need to be developed for greenhouse production.

Case Study –
Precision Agriculture in Greenhouse

Precision Agriculture in Greenhouse

- Precision Agriculture Approach
  - Site-specific cultivation
  - Field Crops
    - Plant Sensing Data
      - Remote Sensing by satellites
    - Position Information
      - Global Positioning System (GPS)

Source: http://www.futuregov.asia

  - **Greenhouses**
    - Plant Sensing Data
      - Ground-Based Sensing (no satellites)
      - Plant-Oriented Remote-Sensing Algorithms
    - Position Information
      - Precision Local Positioning System (PLPS)

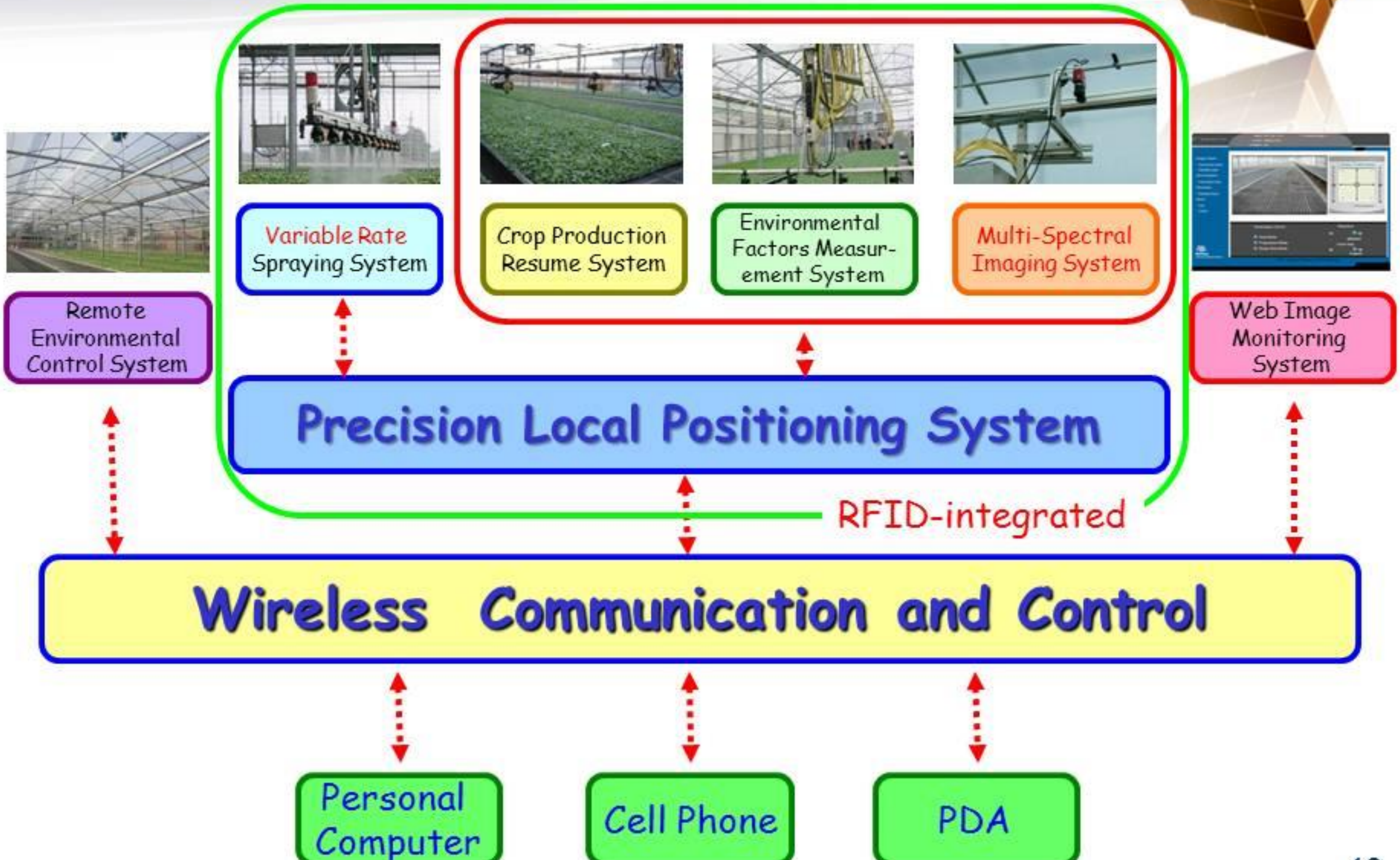
➢ Seedling Nursery

- In Taiwan, vegetable seedlings are cultivated in greenhouses.
- Cabbage seedlings are grown using plug trays in controlled environment.

RFID Management Information System

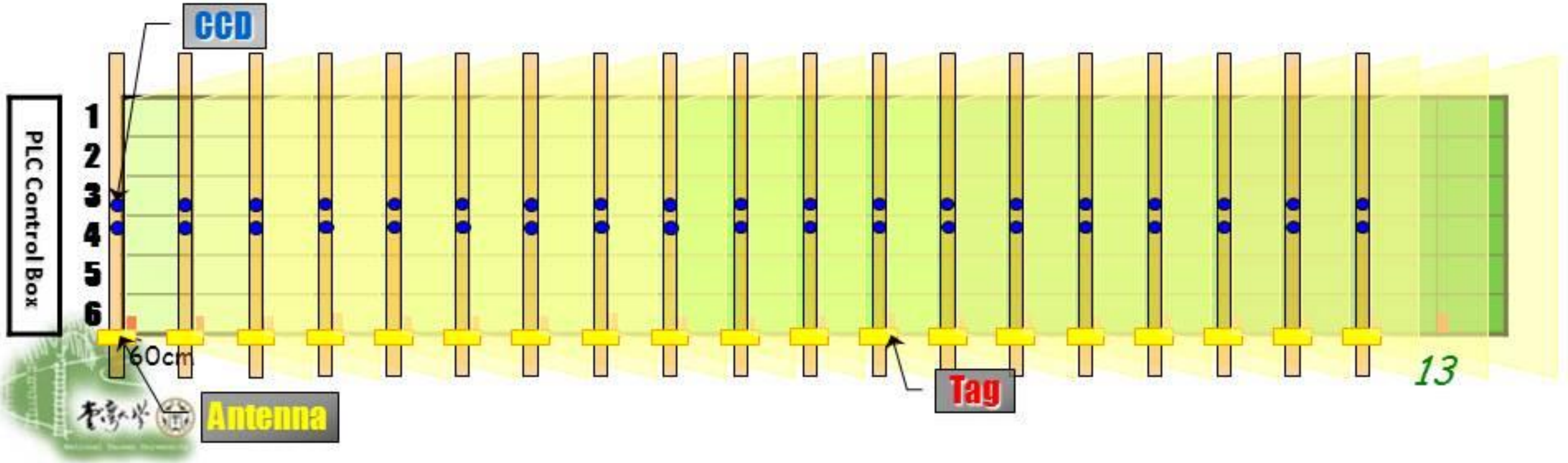
- Remote Sensing and Monitoring
  - ✓ MSIS—Multi-Spectral Imaging System
  - ✓ EFMS—Environmental Factors Measurement System
  - ✓ WIMS—Web Image Monitoring System
- Greenhouse Operations
  - ✓ VRSS—Variable Rate Spraying System
  - ✓ RECS—Remote Environmental Control System
- Production Traceability
  - ✓ CPRS—Crop Production Resume System
    - Environment Resume
    - Management Resume

Remote Sensing and Control Automation of Precision Cultivation

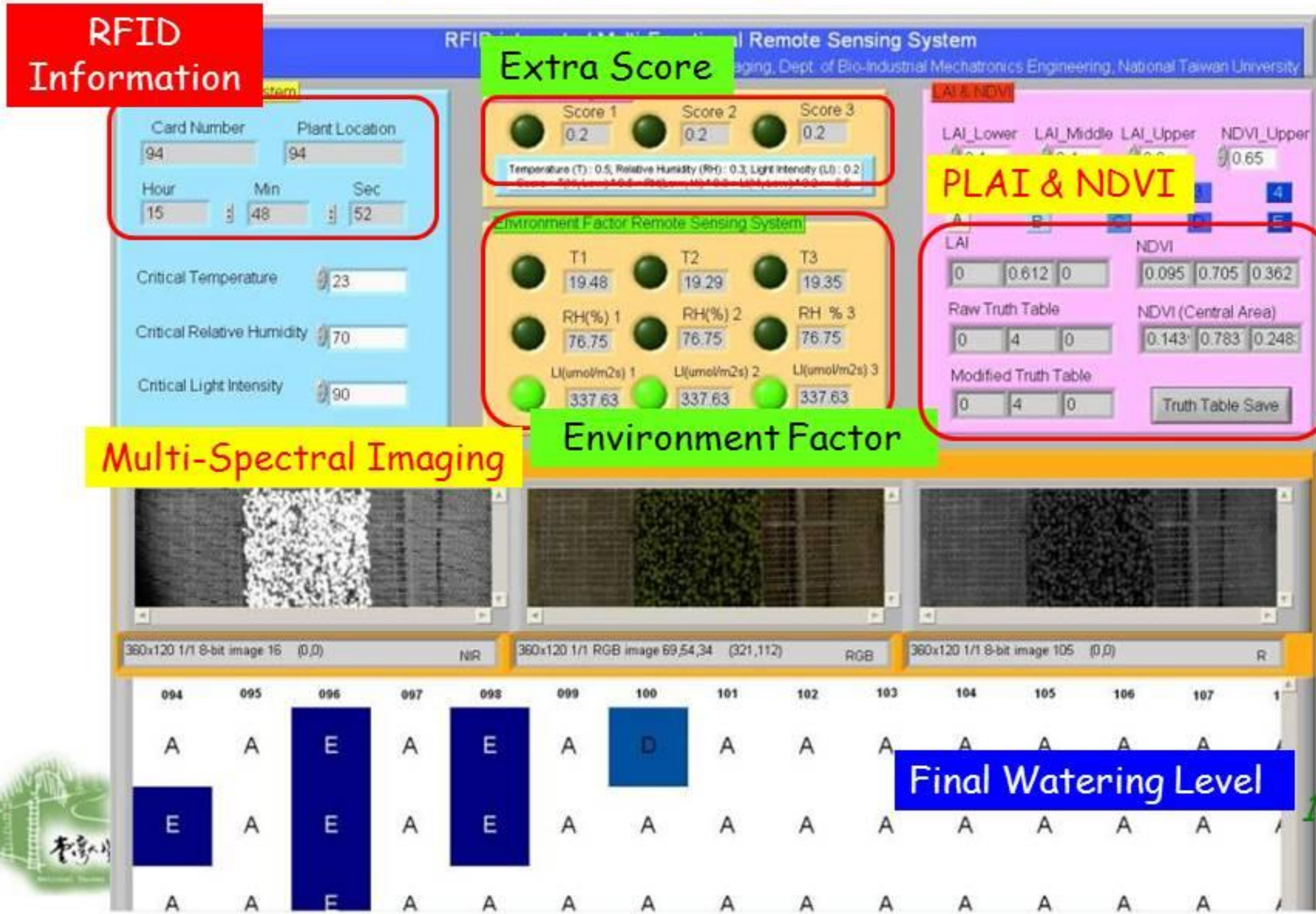


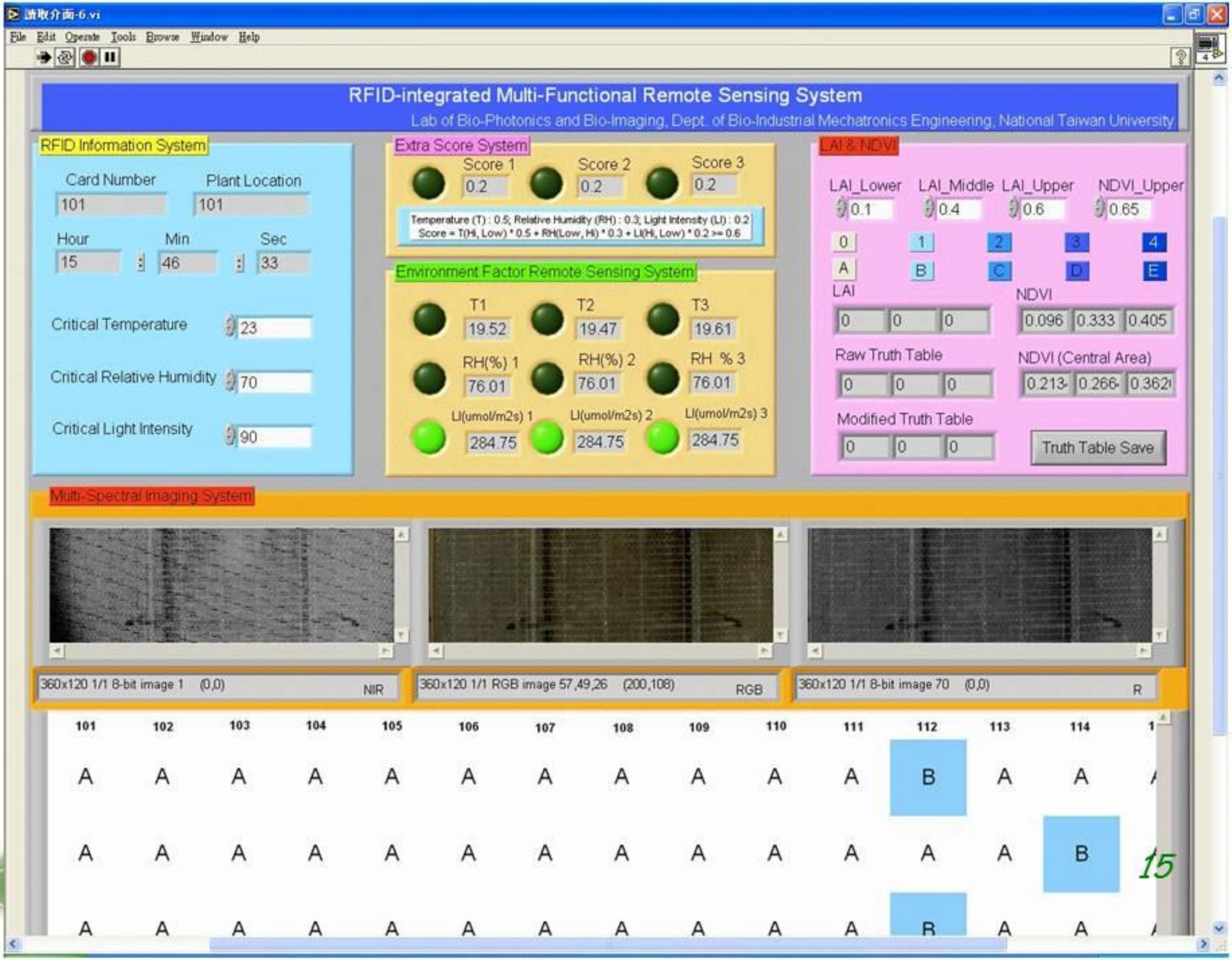
Variable Rate Spraying System

- RFID Tag Detection
- Multi-Spectral Images Grabbing
- Environmental Factor Measurement
- Image Processing and Analysis
- Water Management Decision
- Variable Rate Spraying



Variable Rate Spray System
-- Graphic Programming Control System



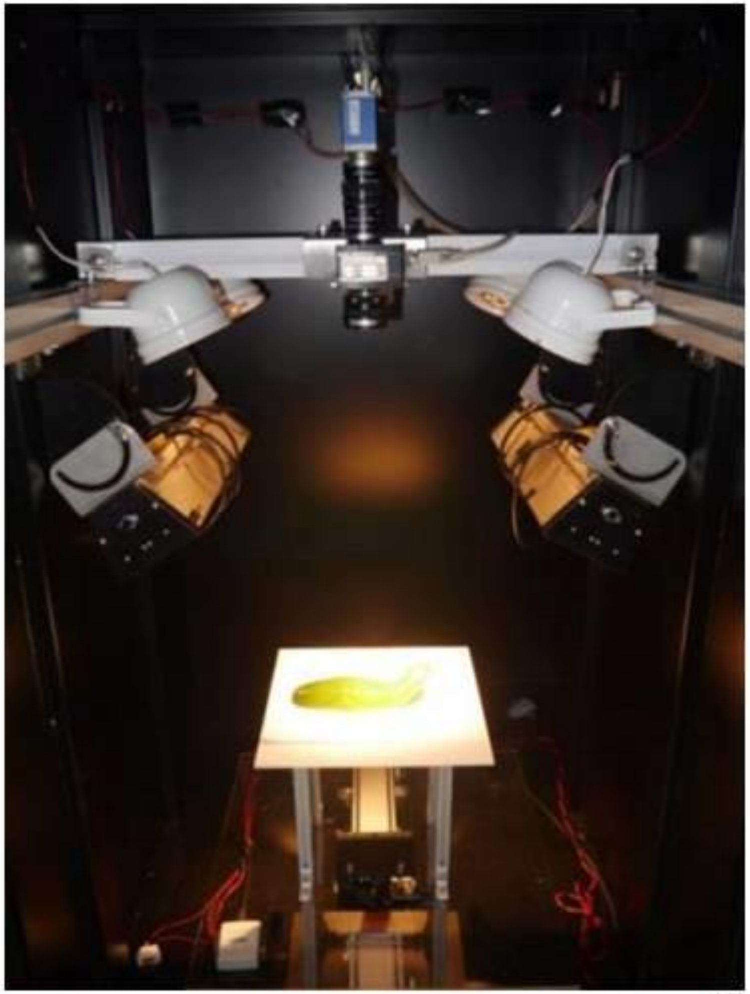


File Edit Operate Tools Browse Window Help
RFID-integrated Multi-Functional Remote Sensing System
Lab of Bio-Photonics and Bio-Imaging, Dept. of Bio-Industrial Mechatronics Engineering, National Taiwan University
RFID Information System
Card Number 101
Plant Location 101
Hour 15 : Min 46 : Sec 33
Critical Temperature 23
Critical Relative Humidity 70
Critical Light Intensity 90
Extra Score System
Score 1 0.2
Score 2 0.2
Score 3 0.2
Temperature (T) : 0.5; Relative Humidity (RH) : 0.3; Light Intensity (LI) : 0.2
Score = T(Hi, Low) * 0.5 + RH(Low, Hi) * 0.3 + LI(Hi, Low) * 0.2 >= 0.6
Environment Factor Remote Sensing System
T1 19.52
T2 19.47
T3 19.61
RH(%) 1 76.01
RH(%) 2 76.01
RH % 3 76.01
LI(umol/m2s) 1 284.75
LI(umol/m2s) 2 284.75
LI(umol/m2s) 3 284.75
LAI & NDVI
LAI_Lower 0.1
LAI_Middle 0.4
LAI_Upper 0.6
NDVI_Upper 0.65
0 1 2 3 4
A B C D E
LAI 0 0 0
NDVI 0.096 0.333 0.405
Raw Truth Table 0 0 0
NDVI (Central Area) 0.213 0.266 0.362
Modified Truth Table 0 0 0
Truth Table Save
Multi-Spectral Imaging System
360x120 1/1 8-bit image 1 (0,0) NIR
360x120 1/1 RGB image 57,49,26 (200,108) RGB
360x120 1/1 8-bit image 70 (0,0) R
101 102 103 104 105 106 107 108 109 110 111 112 113 114
A A A A A A A A A A A B A A
A A A A A A A A A A A A A B
A A A A A A A A A A A B A A

Case Study –
Spectral Imaging Approach to Detect Water Stress of Vegetable

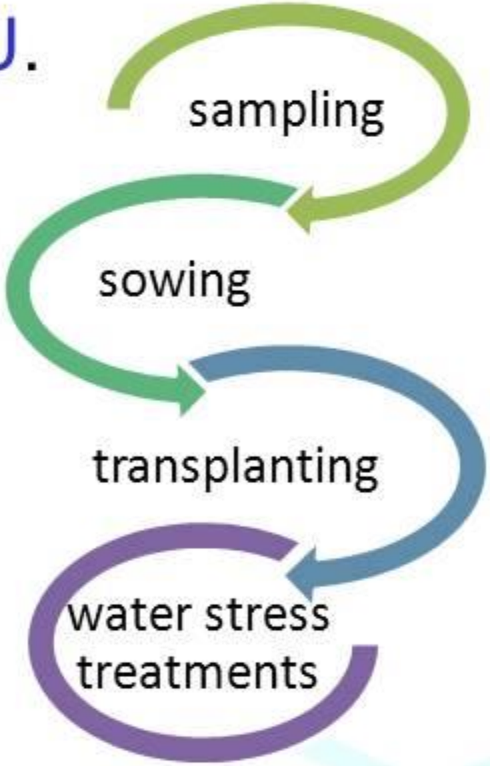
Hyperspectral Imaging System

- Hyperspectral imaging (HSI) system can not only detect the spectrum, but also obtain the information of the image spatial space.
- Hsu *et al*. (2018) developed a HSI system to evaluate *phalaenopsis* flowering quality.



Sample Preparations

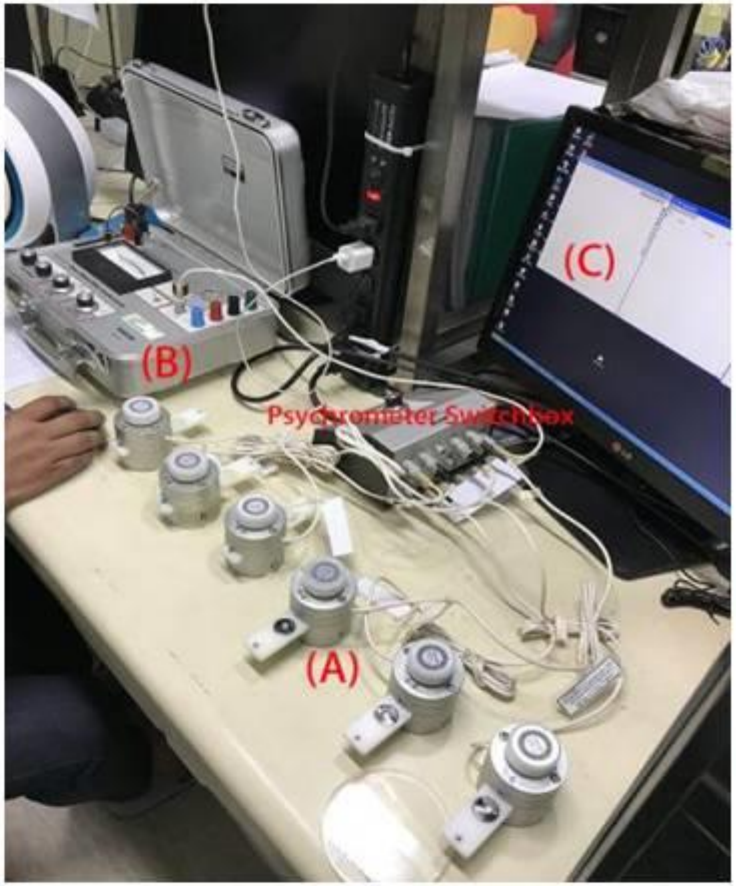
- The leafy vegetable samples used in the experiments were Fengjing Pakchoi (*Brassica rapa L. var. Chinensis* (*Rupr.*) Olsson).
- Cultivated in phytotron of NTU.



Measurement of Water Potential

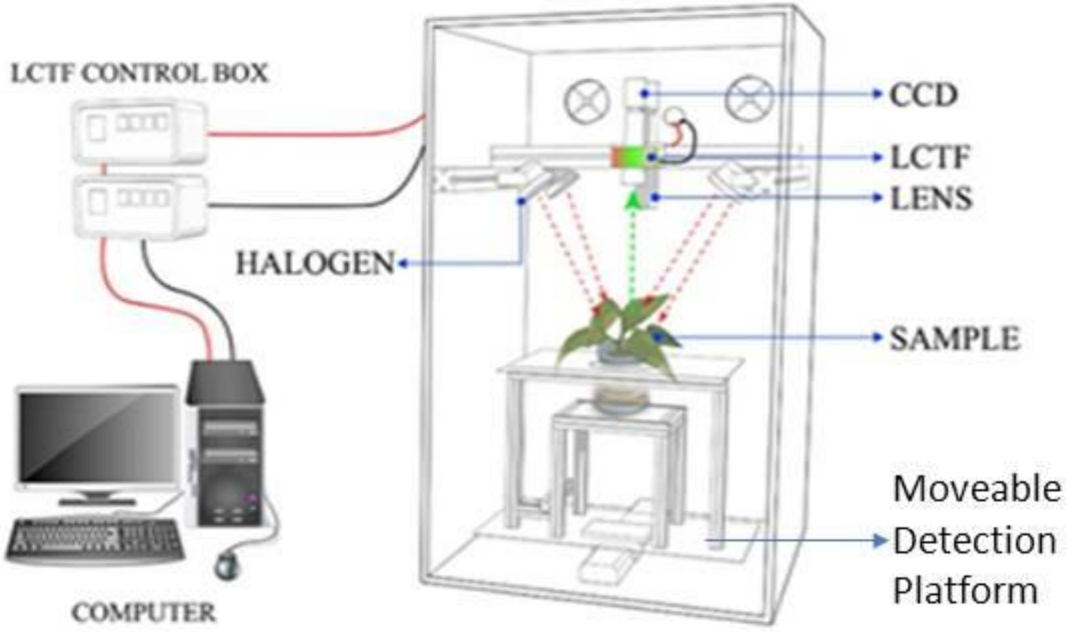
Water potential measurement system (Wescor) includes :

(A) Sample chambers
+ Psycrometer switchbox
(B) Dew point microvoltmeter
(C) PicoLog acquisition software.



Measurement of Spectral Images

- A hyperspectral imaging (HSI) system (Hsu *et al*., 2018) was adopted to capture the spectral images of vegetables.



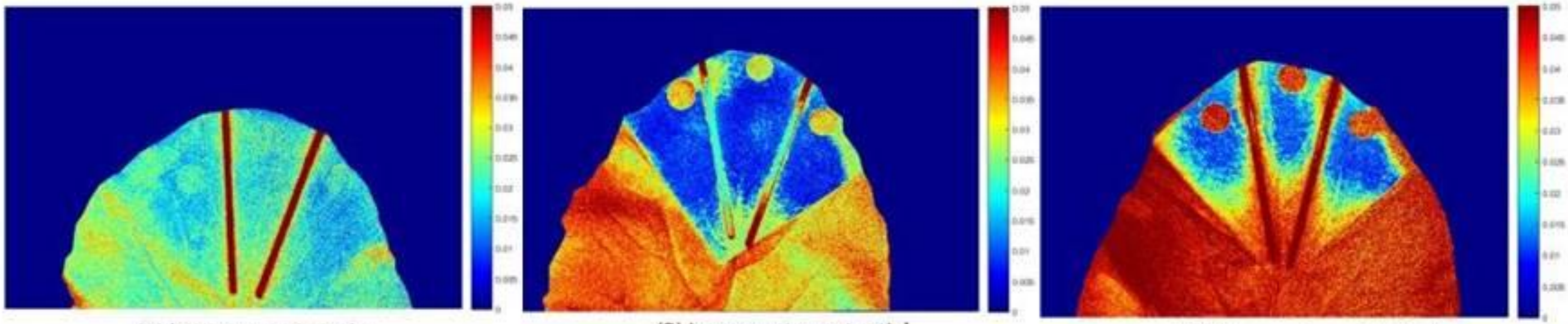
Spectral Analysis

- MPLSR analysis results of hyperspectral imaging in evaluating water potentials of leaves.

Math. Treatment	N	MEAN	SD	SEC	r
(0, 0 ,4 ,1)	48	2.055	0.533	0.341	0.768
(1, 4 ,4 ,1)	48	2.055	0.533	0.301	0.826
(2, 4 ,4 ,1)	48	2.055	0.533	0.305	0.820

Water Potential Distribution

- Pseudocolor Contour Plot to represent the distribution of water potentials on leaves.



(A) better water supply (B) Lower water potential (C) Higher water potential

- It was obvious that the distribution of water potential on vegetable leaf was not uniform.

Thanks for Your Attention

NTU BIME