Remote Sensing and Optical Imaging/Sensing
-- Applications on Rice --

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We would like to acknowledge all staff from Rice Department of Thailand

Reminder from the 1st Lecture

We should choose the *right spectra* with *appropriate sensing & systems* to answer the Needs in each agricultural application

- ✓ Simplicity in Design and Implementation
- ✓ Ease of Use and Operation
- ✓ Affordability
- ✓ Scalability


JASMINE RICE 100%

Thai Hom Mali Rice

- Thai jasmine rice or Khao Dawk Mali (KDML105)
- Good cooking quality
- Impressive fragrance
- One of the most popular rice varieties
- USD 1.73 Billion export

Nitrogen (N) Deficiency Issue

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N is one of the important elements for growth of rice crops

To achieve high yields
Farmers apply too much N fertilizer

disadvantage

- **Cost of rice crop is high**
- **Efficiency of N fertilizer is degraded**
- **The risk of NO_3 pollution is high**

To help balance between the real N demand of rice and N available from soil and additional fertilizers

Several groups try to use tools and management plans in monitoring the N status of the rice field

Based on the fact that…

Chlorophyll content ⟷ **Leaf N concentration**

strongly correlated

Proposed approach:

➢ **Chlorophyll meter**

advantage

- **A simple**
- **Fast**
- **Non-destructive way**

disadvantage

- **Transmissive operation**
  - both sides of the leaf under the evaluation are clean and no defect
- **Expensive**
  - in a few-thousand USD

SPAD

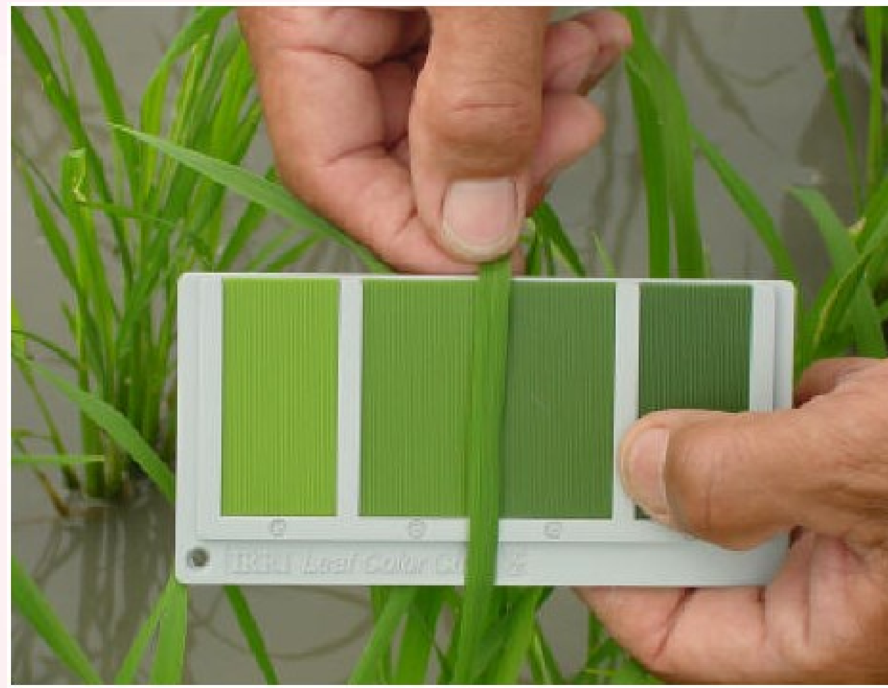
λ: 650 nm + 940 nm

Low-cost approach:

➤ **Leaf Color Chart (LCC)**

advantage

- **Very cheap (USD1)**
- **No waste produced**
- **Easy to use**



Incorrect visual reading of colors **leads to** **Improper application of N fertilizers**

A more accurate but not expensive tool is needed

Our Solution

Analyzed Scattering Light from Leaf

LED **562-nm**	**+**	**Si-Photodetector**	**+**	**Microcontroller** **controlling and processing**	**+**	**Simple Electrical Noise Rejector**

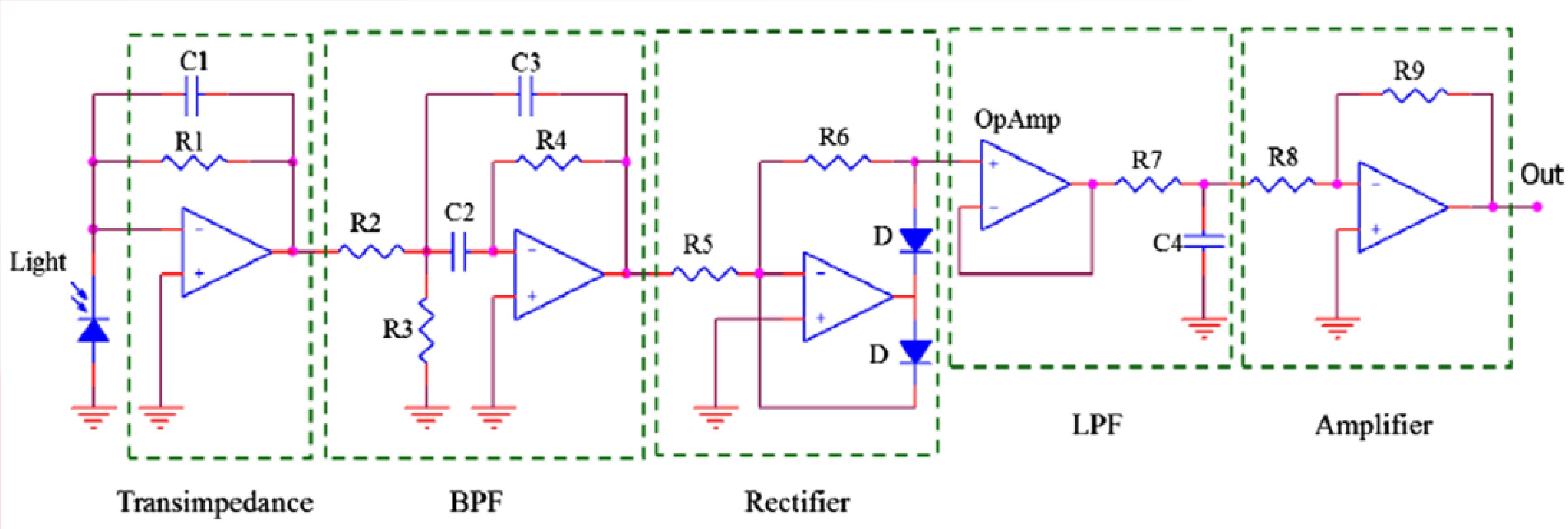
Outside View of Our Low-Cost LED-based Leaf Color Meter Prototype

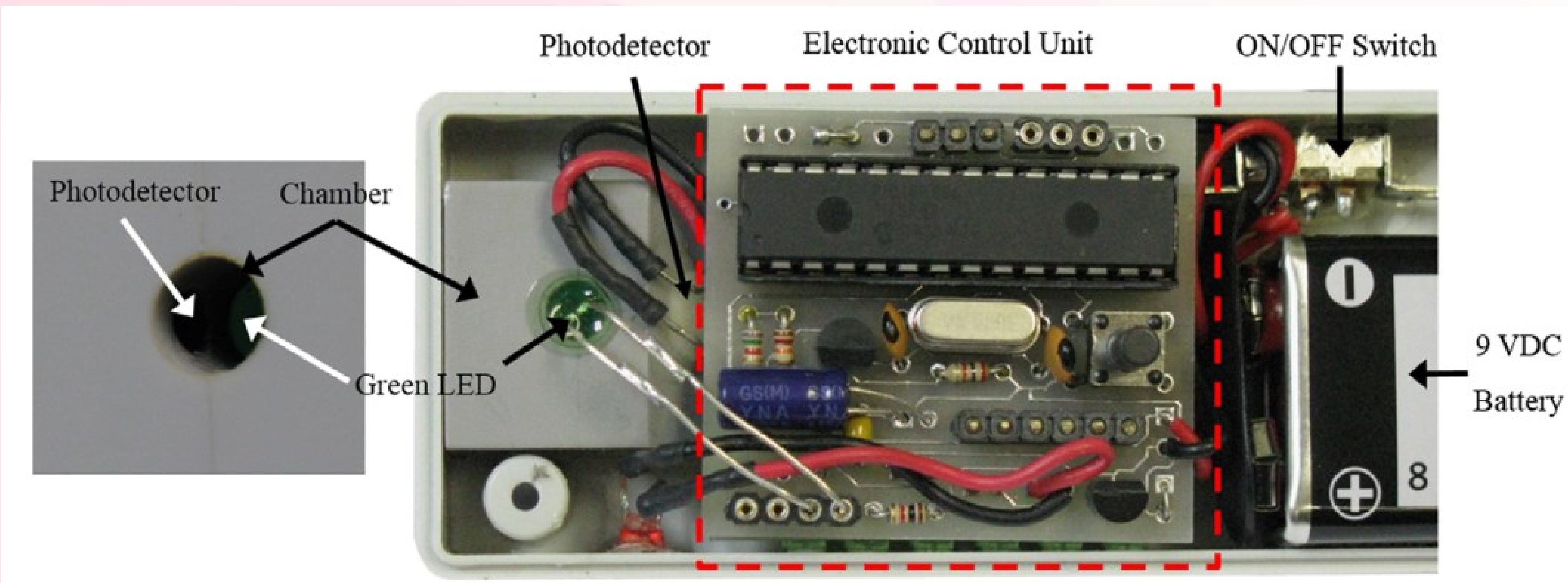
Measuring Area
Ø5-mm

Red LED

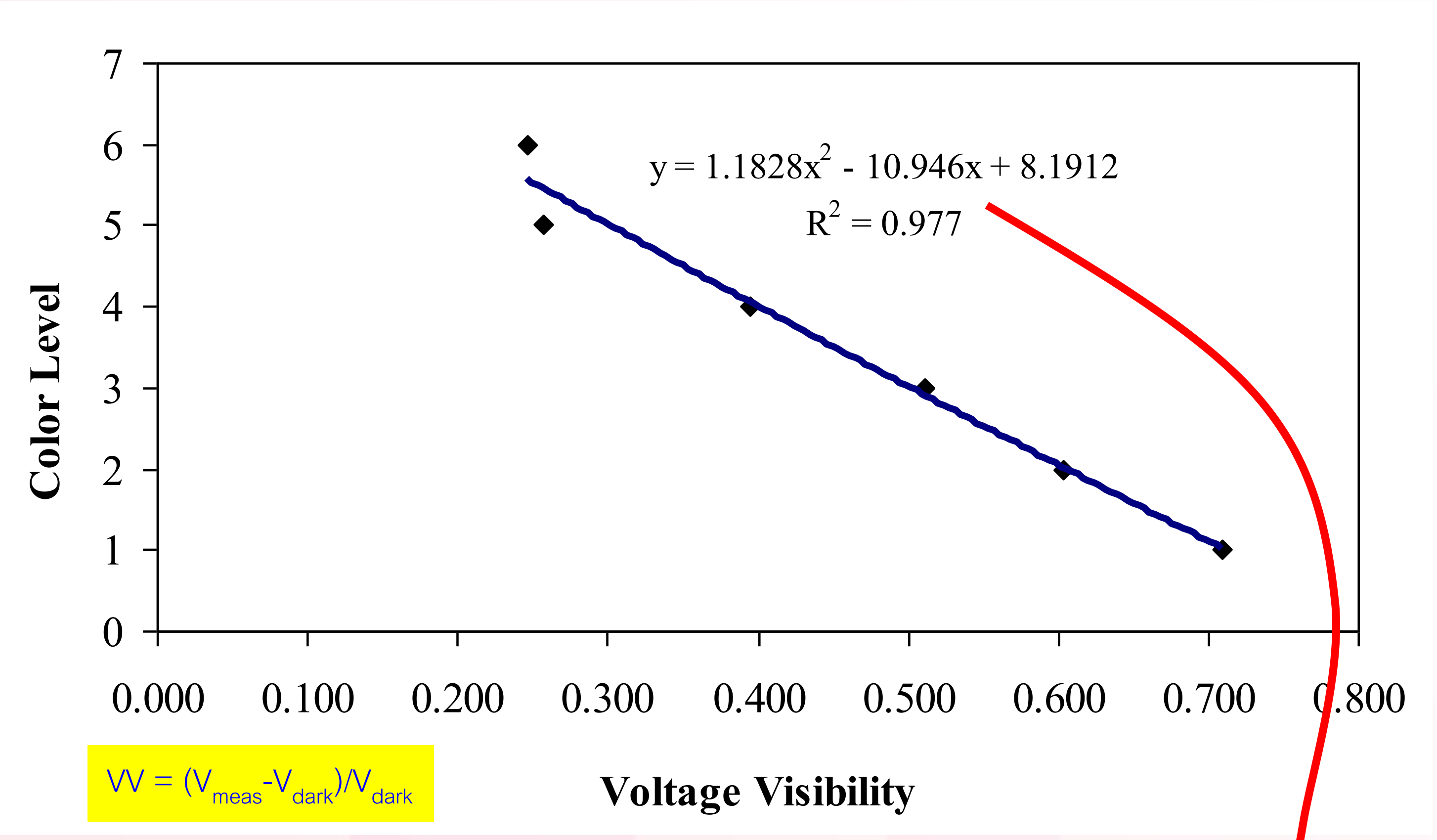
- A compact $40\times120\times25$-mm^3 plastic box
- 120 grams of weight
- ~USD39 of total cost

S. Sumriddetchkajorn and Y. Intaravanne, *Optics and Lasers in Engineering*, Vol. 53, pp. 179-184, February 2014.


C1
R1
C3
R4
R6
OpAmp
R9
R7
R8
Out
R2
C2
Light
R5
D
C4
R3
D
LPF
Amplifier
Transimpedance
BPF
Rectifier

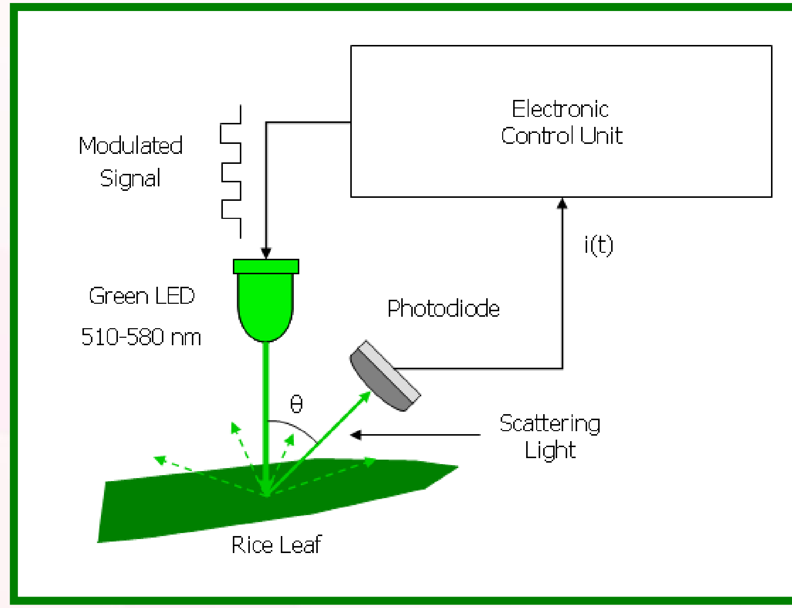

Photodetector
Electronic Control Unit
ON/OFF Switch
Photodetector
Chamber
Green LED
9 VDC
Battery

Calibration Curve



Stored in Our Prototype

Bai-Khao: Nitrogen Esitmator for Rice Field



Features

- High accuracy with 6 levels of color
- Low energy consumption:
  5VDC 20 mA (operating mode)
  5VDC 10 mA (standby mode)
- Compact and lightweight:
  (WxLxH) 40×120 ×25 mm^3
  120 grams

Examples of fertilization rates:

- **Tillering Stage**

Color level < 3: Urea fertilizer 12 kg/rai
Color level = 3: Urea fertilizer 8.5 kg/rai
Color level > 3: Urea fertilizer 5 kg/rai

- **Panicle Initiation Stage**

Color level < 3: Urea fertilizer 16 kg/rai
Color level = 3: Urea fertilizer 12.5 kg/rai
Color level > 3: Urea fertilizer 9 kg/rai

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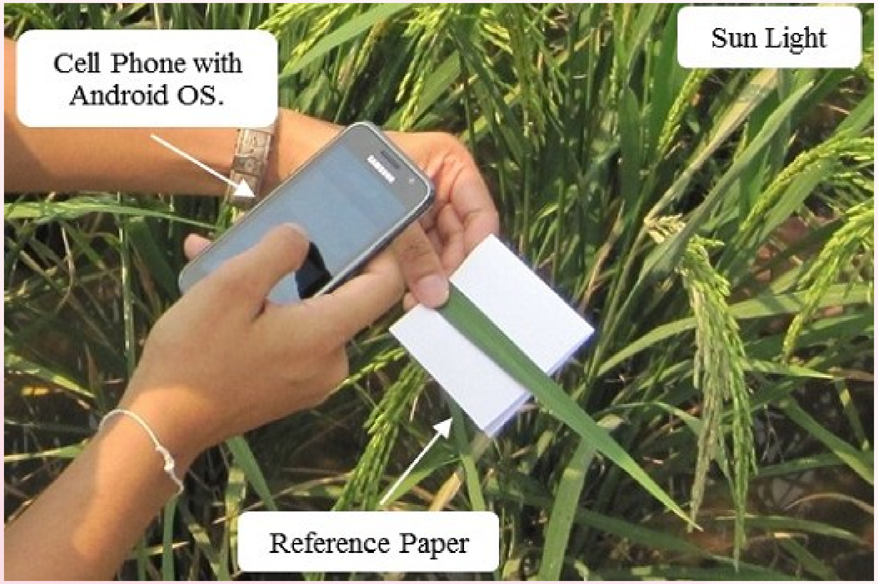
How to deliver to all farmers?

- Easy to scale it up
- Fast calibration
- Fast delivery

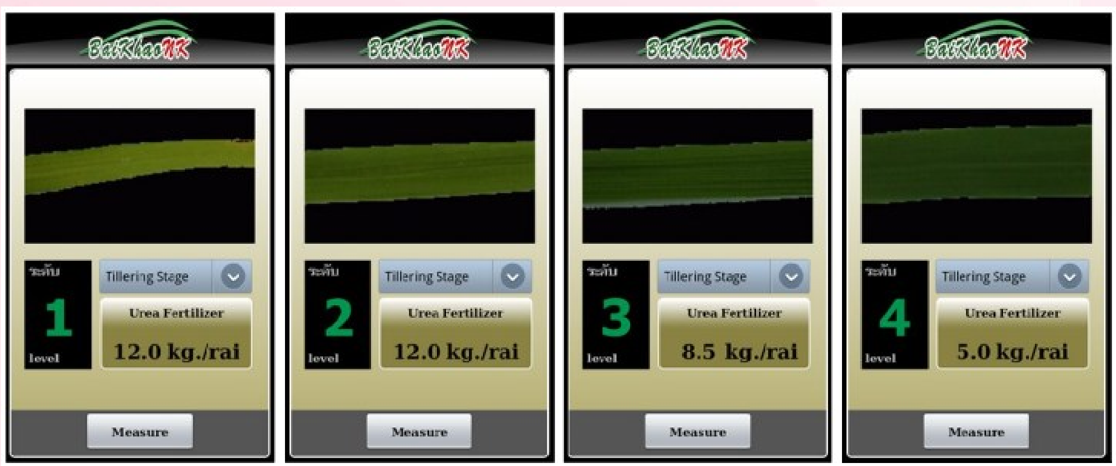
Mobile Device-based Nitrogen Estimator for Rice Field



Features

- High accuracy with 5 color levels of the rice leaf
- Estimation of potassium deficiency
- Operated on a mobile device equipped with at least Android 2.2 operating system

Examples of fertilization rates:



- **Tillering Stage**

Color level < 3: Urea fertilizer 12 kg/rai
Color level = 3: Urea fertilizer 8.5 kg/rai
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- **Panicle Initiation Stage**

Color level < 3: Urea fertilizer 16 kg/rai
Color level = 3: Urea fertilizer 12.5 kg/rai
Color level > 3: Urea fertilizer 9 kg/rai

Y. Intaravanne and S. Sumriddetchkajorn, *Proc. SPIE*, Vol. 8558, pp. 85580F, Beijing, China, November 2012.
Y. Intaravanne and S. Sumriddetchkajorn, *Comp. Elect. in Agriculture*, Vol. 116, pp. 228-233,2015.

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National Electronics and Computer Technology Center

asia research news 2014

A ResearchSEA publication to highlight research in Asia

Rice leaf app for smarter farming

A Thai research team has developed an app to help farmers estimate more accurately the amount of nitrogen-based fertilisers needed in rice fields.

The app could help to reduce the cost of rice crops by cutting excess fertiliser usage, improve the recovery of fertiliser and prevent nitrogen oxide pollution in water.

The simplest way of estimating the amount of fertiliser needed in rice fields is to visually inspect the rice leaves and compare their colours to a standard leaf colour chart. However, an incorrect reading of the chart often leads to an incorrect application of fertiliser. The new app, developed by researchers at the National Electronics and Computer Technology Center in Thailand, effectively turns a smartphone or tablet into a colorimeter that can measure the colour of leaves and recommend the amount of fertiliser to use.

The app uses the device's camera to capture an image of a rice leaf and analyse its colour. Accuracy is achieved by comparing the colour of the leaf to a white reference, such as a piece of paper, that the user holds directly behind the leaf during image capture. The colour is then equated to a standard level on the leaf colour chart and the app displays the amount of fertiliser needed. It can also estimate potassium deficiency. In field tests, the app achieved over 93% accuracy in estimating leaf colours.

Called BaiKhaoNK (after the Thai word BaiKhao, meaning rice leaf), the app is currently compatible with Android 2.2 smartphones and above. This year, the researchers are planning to work with the Department of Rice in Thailand's Ministry of Agriculture and Cooperatives and the National Center for Genetics Engineering and Biotechnology to promote the use of the app with farmers.

For further information contact:
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Unwanted Mixture of Rice Varieties

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Problem

- False mixture with other rice varieties **having similar dimensions and weight/seed as well as amylose content**

KDML105

Average Weight ≈ 0.0216 g/grain
Average Length ≈ 0.734 mm/grain
Average Width ≈ 0.216 mm/grain

Mixed

CNT1

Average Weight ≈ 0.0213 g/grain
Average Length ≈ 0.772 mm/grain
Average Width ≈ 0.206 mm/grain

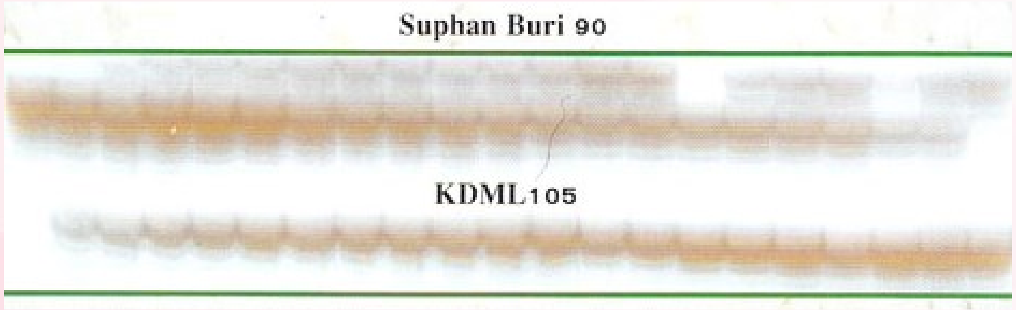
PTT1

Average Weight ≈ 0.0174 g/grain
Average Length ≈ 0.723 mm/grain
Average Width ≈ 0.209 mm/grain

- **Unqualified milled rice products for export**
- **Unwanted rice seed for next plants**

Widely Used Destructive Identification Methods

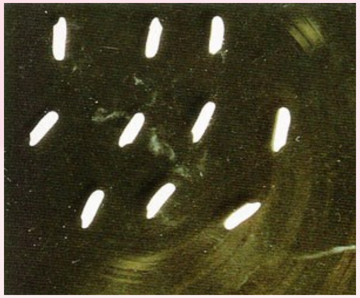
- **DNA Technology**



Advantage
- 100% accuracy

Disadvantages
- Expensive
- Time consuming (3-5 days)

- **Alkaline Spreading Value**


Spreading 1


Spreading 5

For example

KDML105


Level 6-7

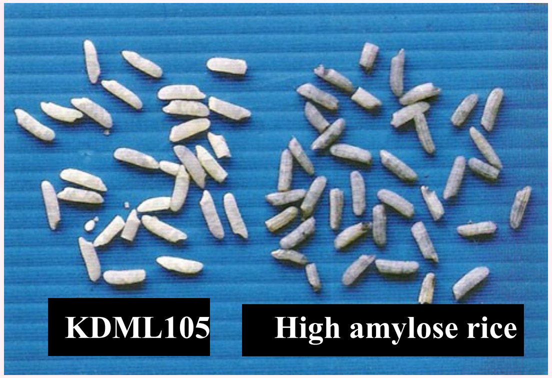

≤ Level 5

CNT1

Advantages
- ~ 70% accuracy

Disadvantage
- Time consuming (at least 23 hrs.)

- **Iodine Binding Technique**



Advantage
- Easy

Disadvantage
- Good for only rice varieties having large difference in amylose content

- **Boiling Technique**

Advantage
- Easy
- ~ 90% accuracy

Disadvantages
- Time consuming (at least 17 minutes)
- High energy consumption

Current Non-Destructive Identification Methods

- **Reflectance Near Infrared Spectroscopy**

  - Slow
  - Needs Complicated mathematical analysis

- **Photoluminescent Technique**

  - Slow
  - Suitable for milled rice grains with large difference in amount of amylose content or level of glutinousness

Our Need

- **No Waste Produced**
  (i.e., non destructive approach)
- **Fast Enough**
- **Moderate Accuracy**

How ?

High Energy Excitation
(induced fluorescent radiation)

+

Multispectral Imaging Technology and Analytics
(only two-wavelength is needed)

Our Proposed Rice Breed Identification System

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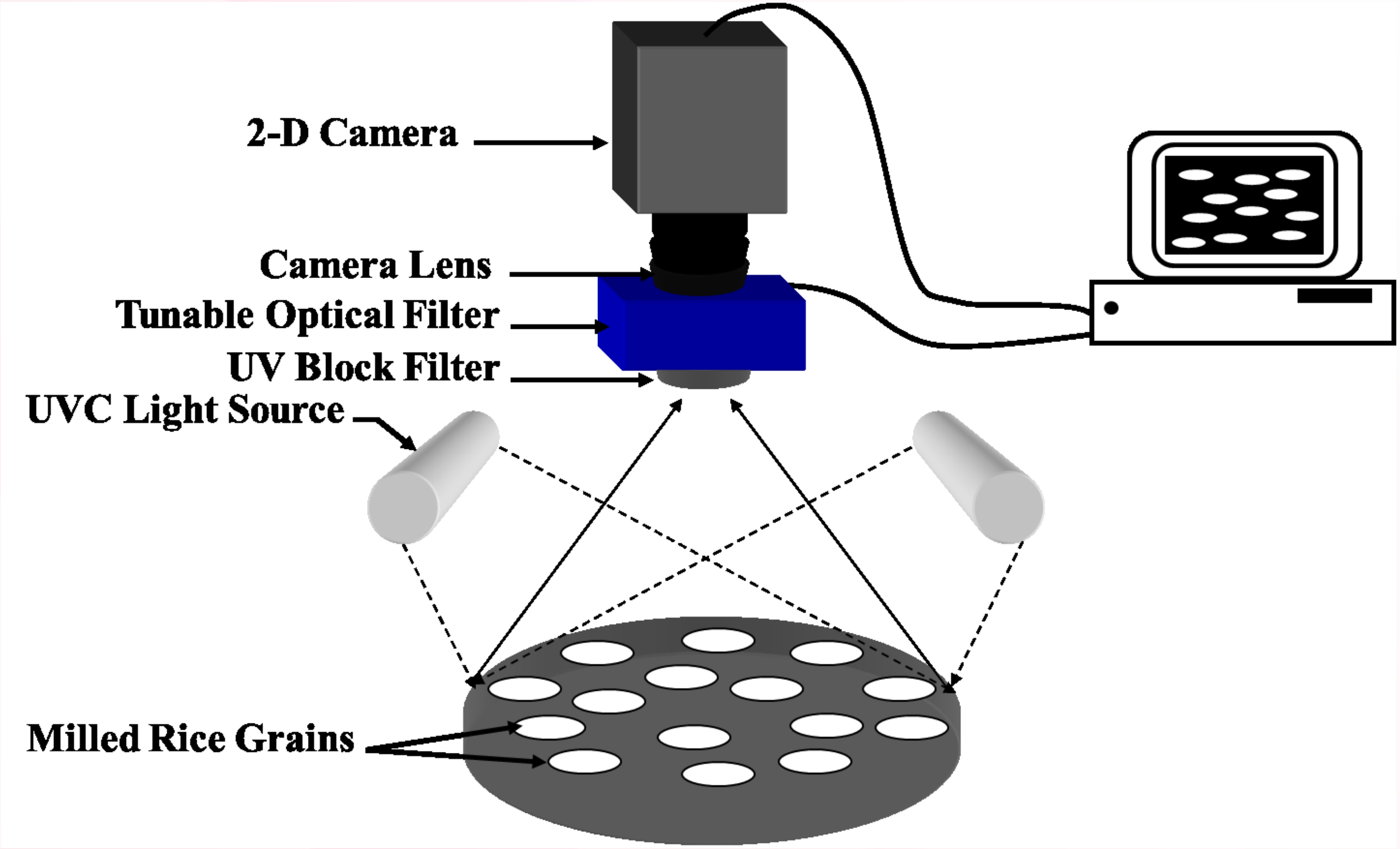
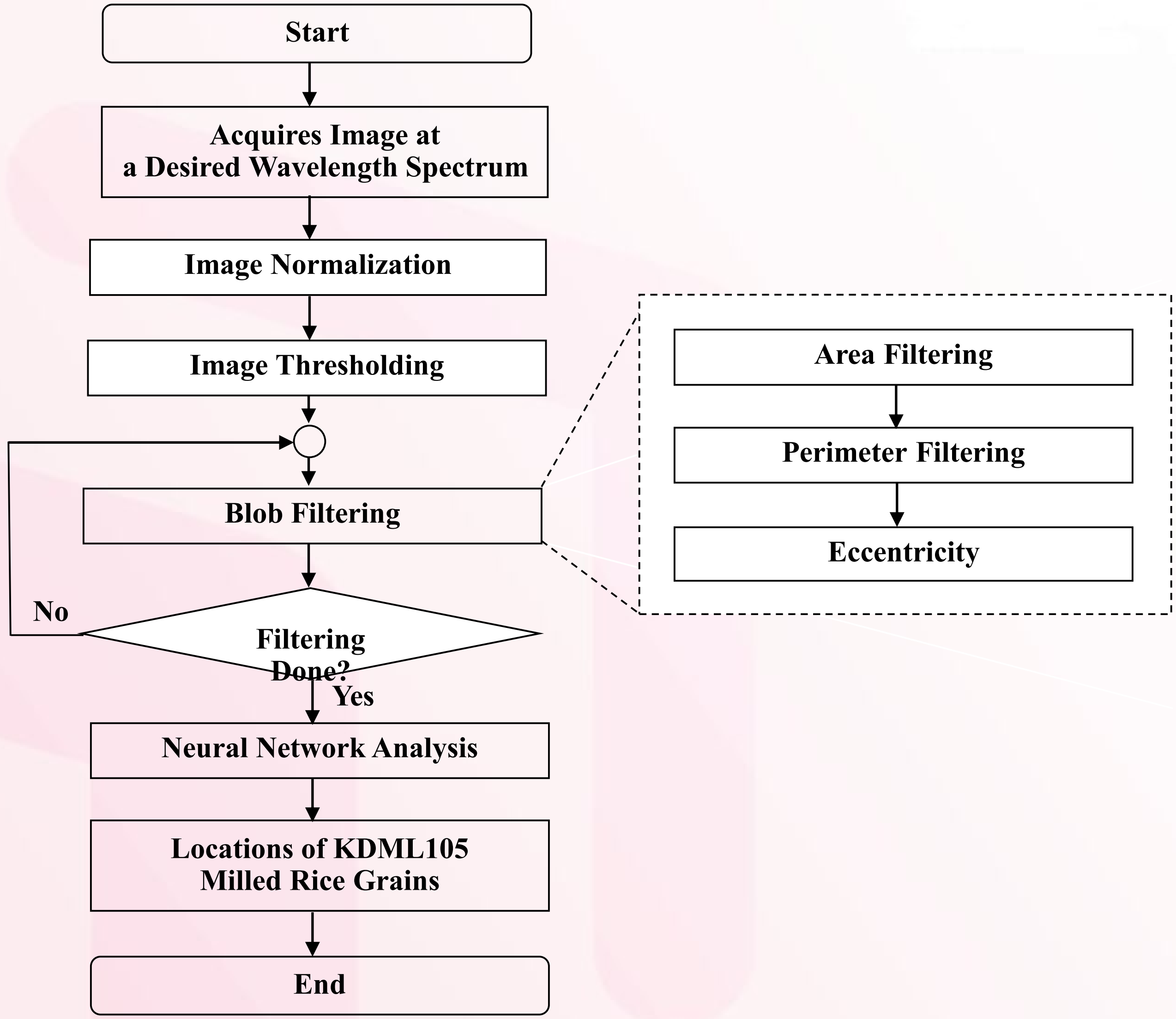
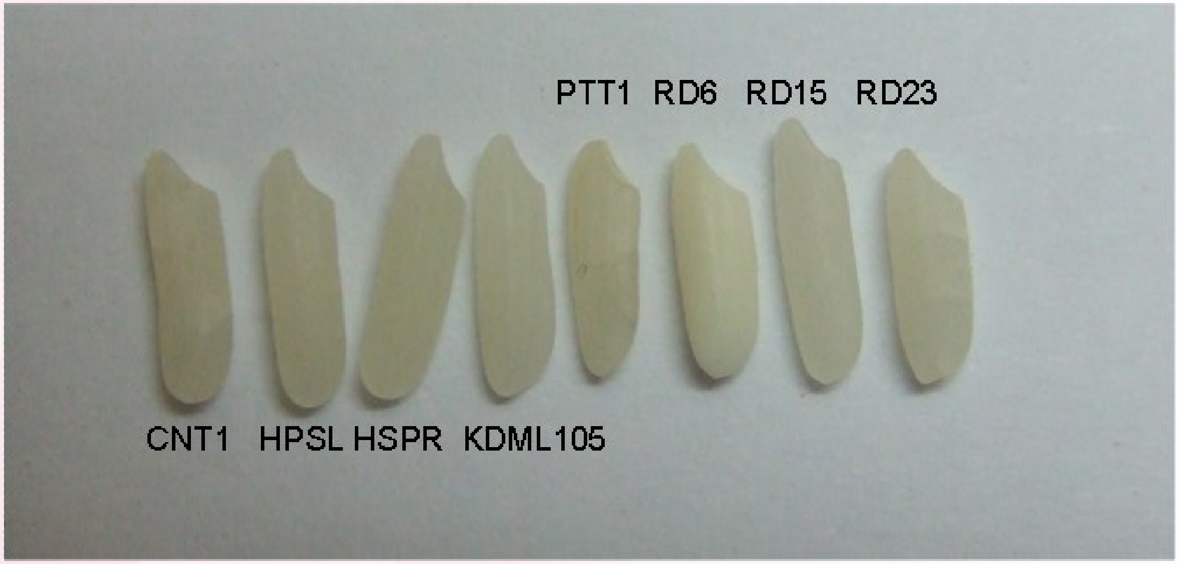
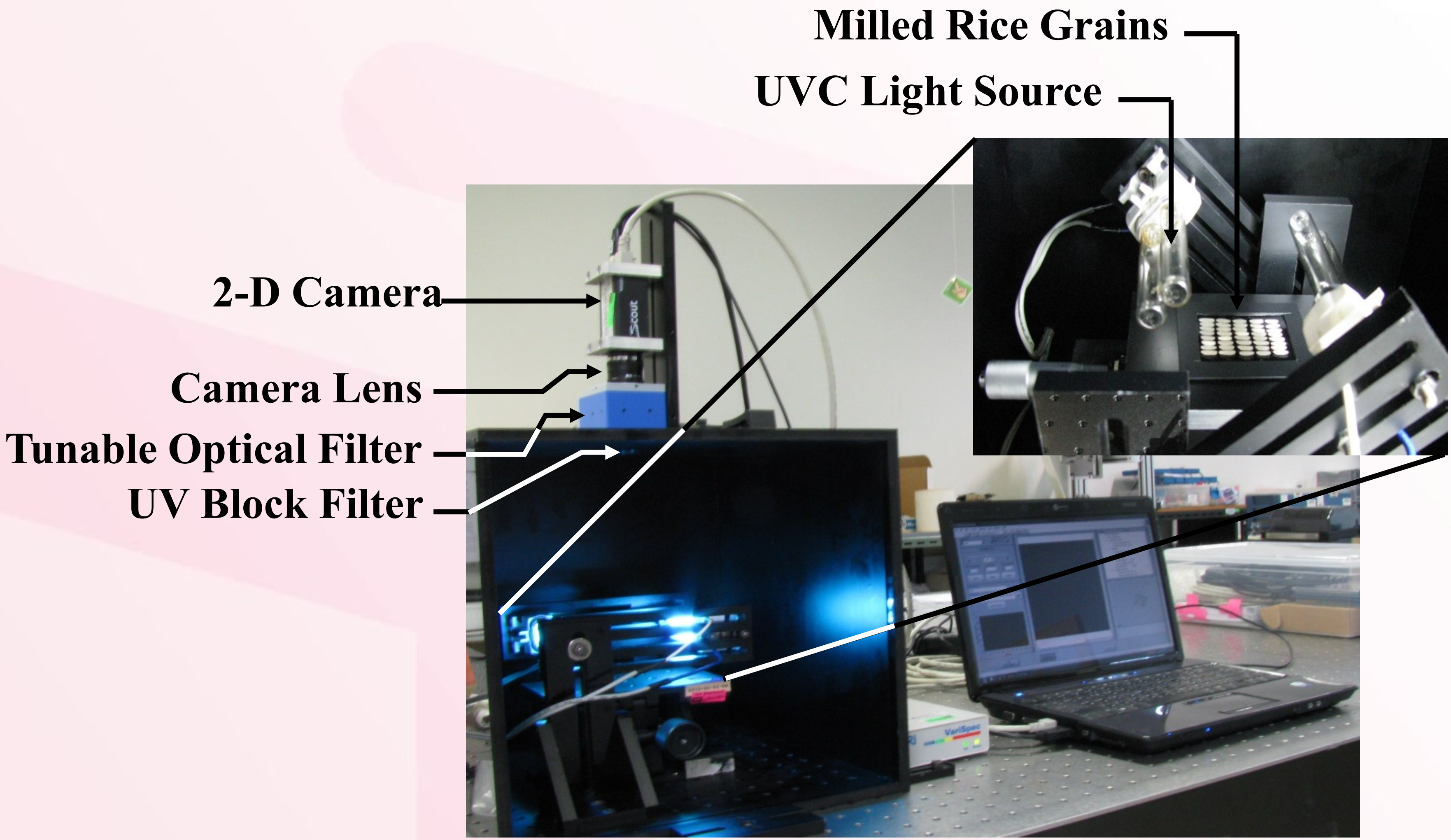



Start
Acquires Image at
a Desired Wavelength Spectrum
Image Normalization
Image Thresholding
Blob Filtering
No
Filtering
Done?
Yes
Neural Network Analysis
Locations of KDML105
Milled Rice Grains
End
Area Filtering
Perimeter Filtering
Eccentricity

CNT1: Chai Nat 1
HPSL: Hom Pitsanulok
HSPR: Hom Supanburi
KDML105: Khao Dawk Mali 105

PTT1: Pathumthani 1
RD6: Thai Sticky Rice
RD15: Ko Kor 15
RD23: Ko Kor 23

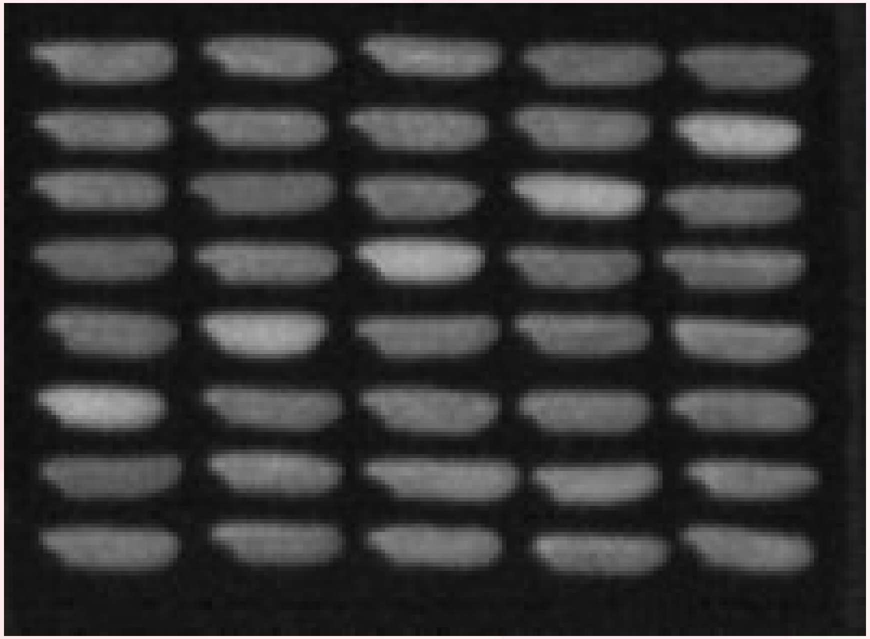



Milled Rice Grains
UVC Light Source
2-D Camera
Camera Lens
Tunable Optical Filter
UV Block Filter
Scout
VariSpec

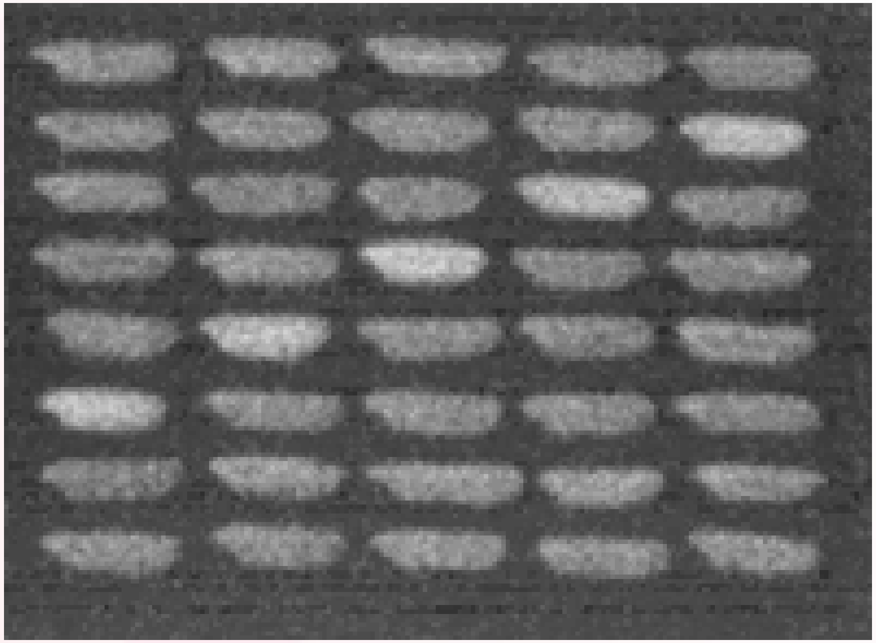
CNT1	HPSL	HSPR	KDML105	PTT1
HPSL	HSPR	KDML105	PTT1	RD6
HSPR	KDML105	PTT1	RD6	RD15
KDML105	PTT1	RD6	RD15	RD23
PTT1	RD6	RD15	RD23	CNT1
RD6	RD15	RD23	CNT1	HPSL
RD15	RD23	CNT1	HPSL	HSPR
RD23	CNT1	HPSL	HSPR	KDML105

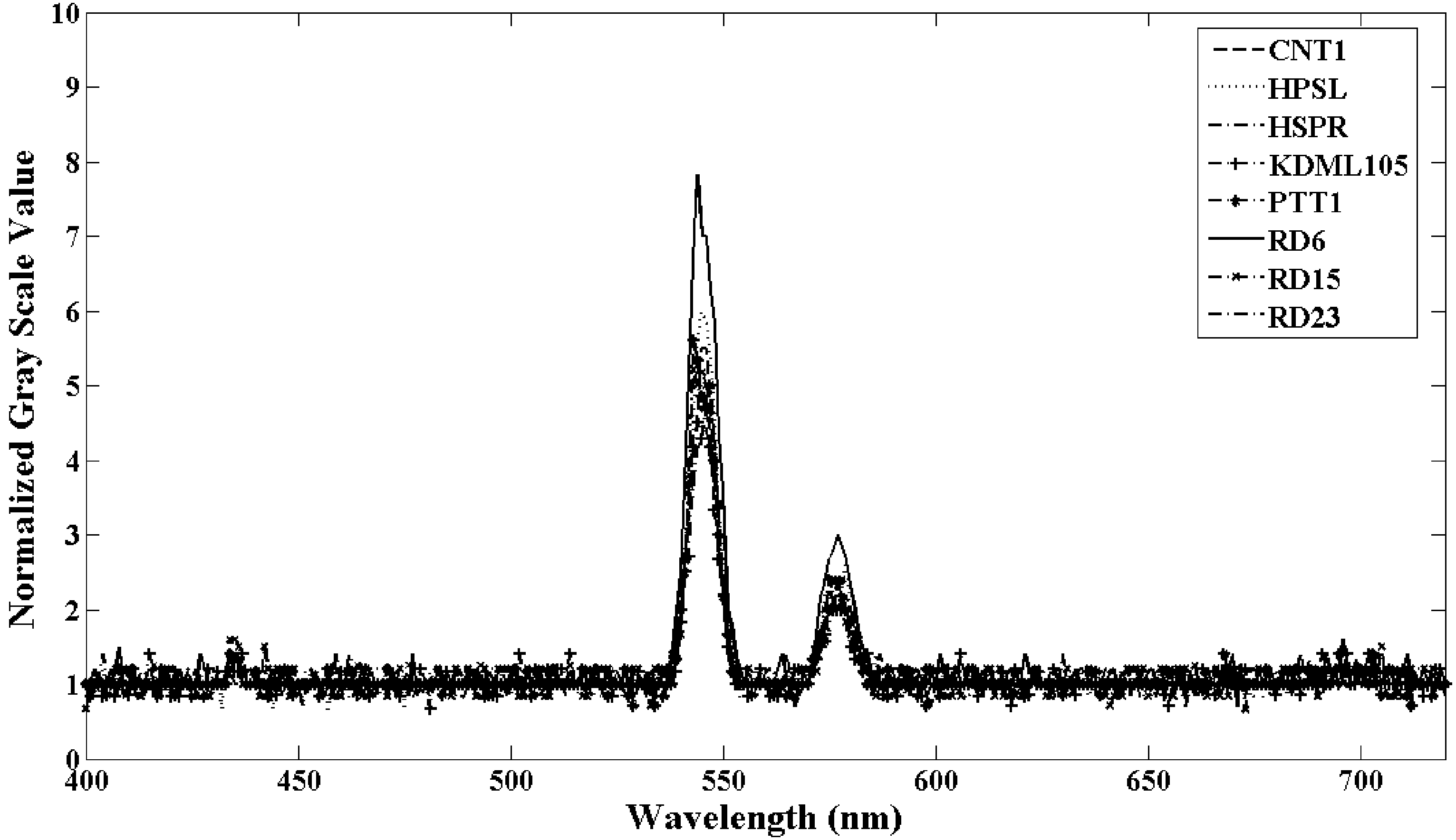
KDML105	PTT1	RD6	RD15	RD23
PTT1	RD6	RD15	RD23	CNT1
RD6	RD15	RD23	CNT1	HPSL
RD15	RD23	CNT1	HPSL	HSPR
RD23	CNT1	HPSL	HSPR	KDML105
CNT1	HPSL	HSPR	KDML105	PTT1
HPSL	HSPR	KDML105	PTT1	RD6
HSPR	KDML105	PTT1	RD6	RD15

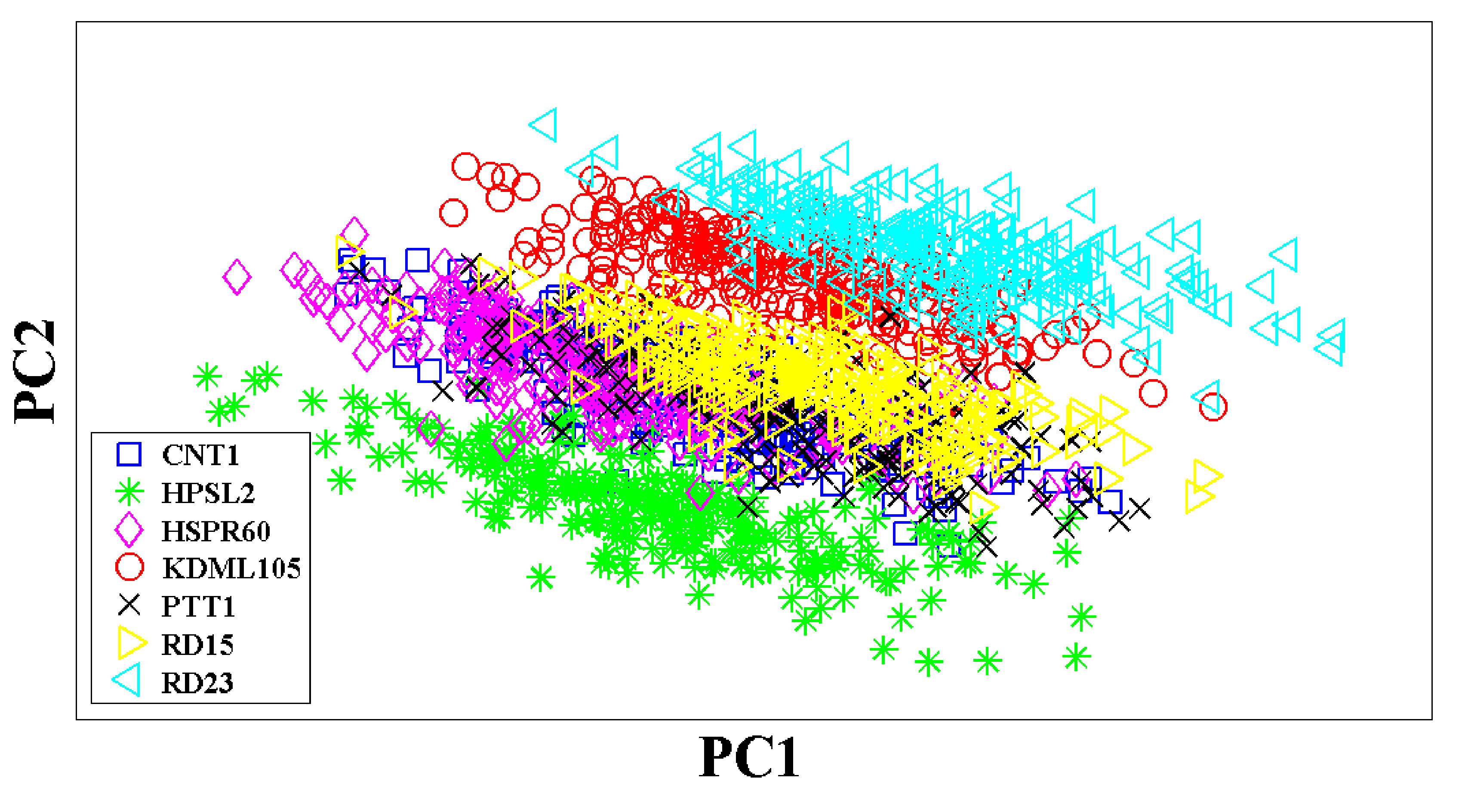
Image under Visible Light



Fluorescent Image

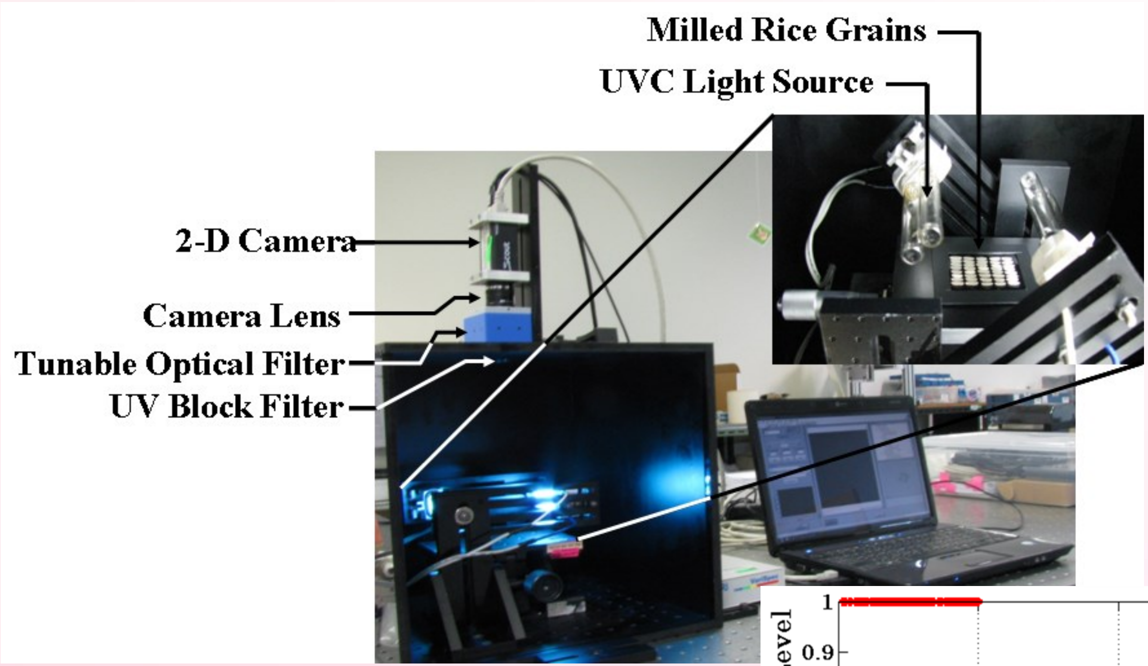



CNT1
HPSL
HSPR
KDML105
PTT1
RD6
RD15
RD23
Normalized Gray Scale Value
Wavelength (nm)
0
1
2
3
4
5
6
7
8
9
10
400
450
500
550
600
650
700



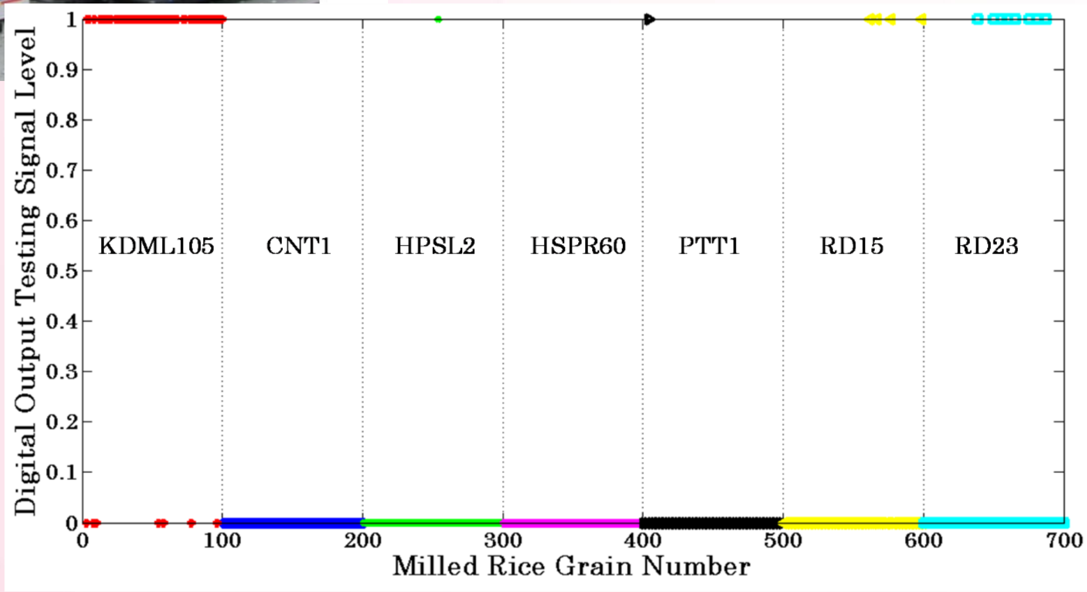
PC2
PC1
CNT1
HPSL2
HSPR60
KDML105
PTT1
RD15
RD23

Thai Jasmine Rice Identification System



Fluorescent Imaging
+
Neural Network Analysis

Accuracy: 80%
Calculation time: 25 ms



Improvement is still needed for practical use

K. Suwansukho, S. Sumriddetchkajorn and P. Buranasiri, *Applied Optics*, Vol. 50, No. 21, pp. 4024-4030, July 2011.

Quality Control of Rice Seeds/Grains

- **Physical Dimensions Parameter**

Disadvantages

- ❑ **Requires a well-trained person**
- ❑ **Takes a long time (20 seconds) to measure for one rice sample**

Proposed Solution

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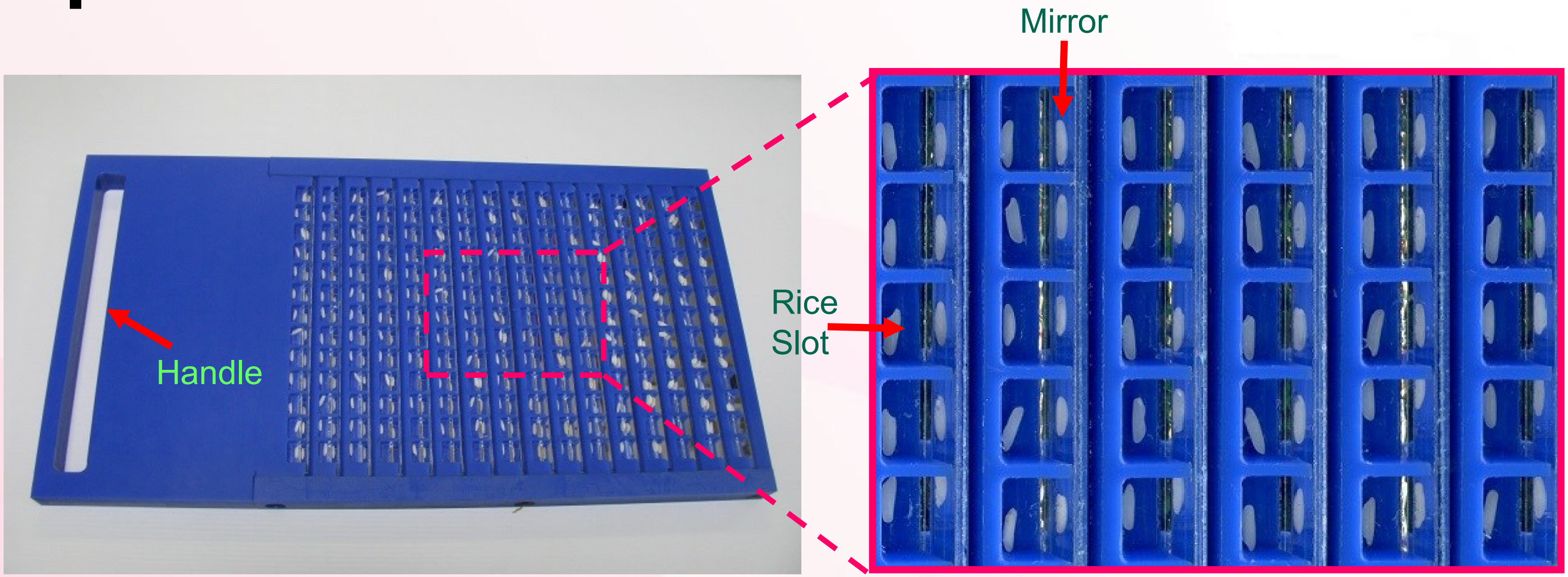

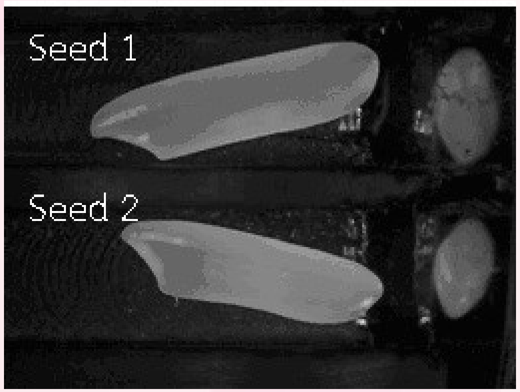

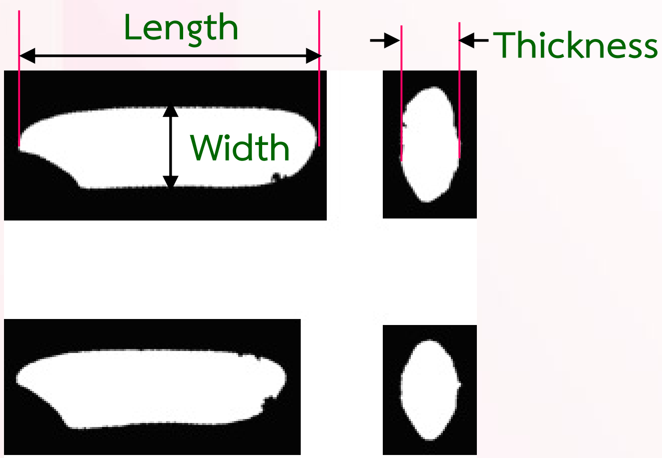

S. Sumriddetchkajorn, Y. Intaravanne, and S. Chanhorm, *Proc. SPIE*, Vol. 8883, pp. 88830M, Chonburi, Thailand, May 2013.

S-Rice: *Rice Quality Analyzer*

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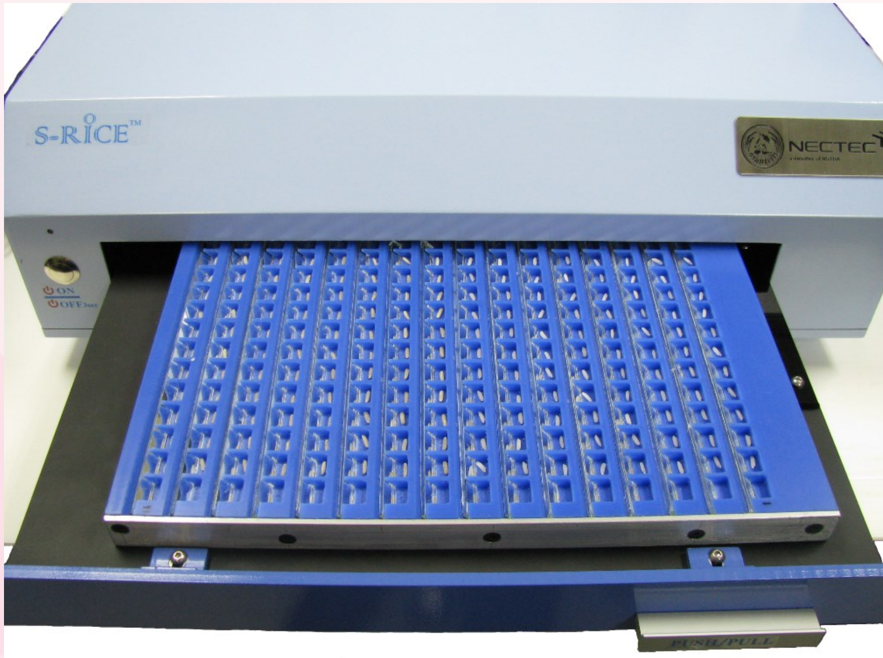
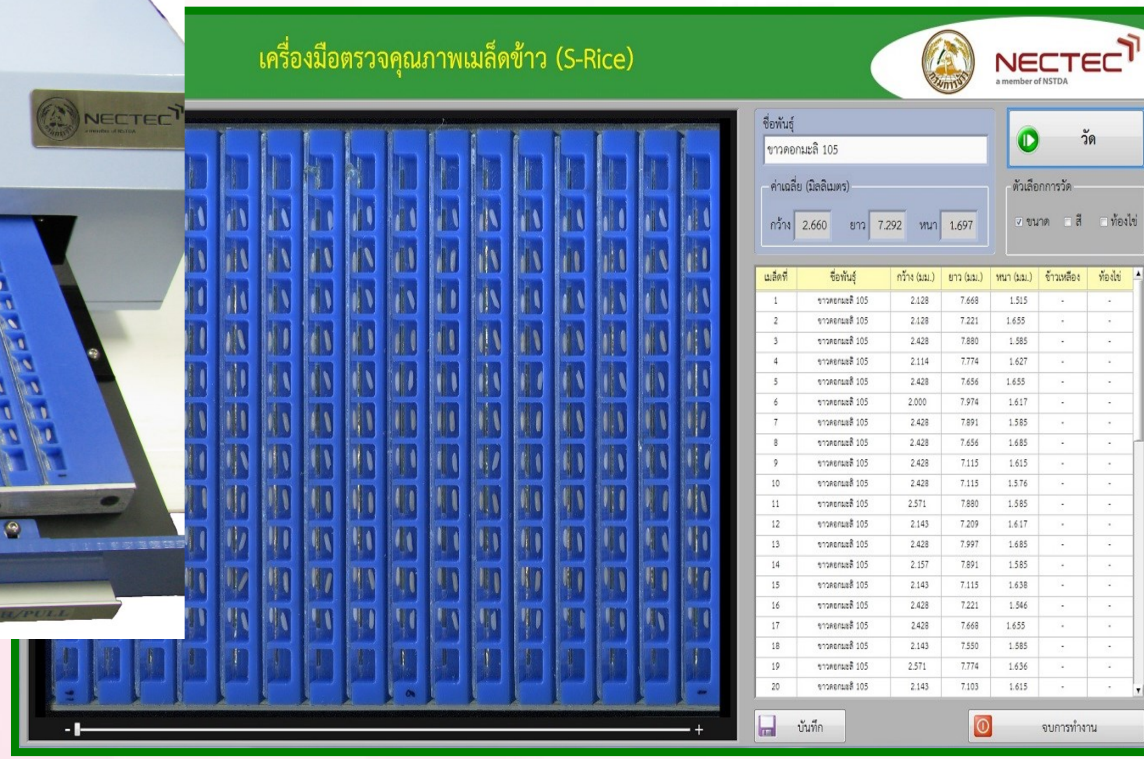
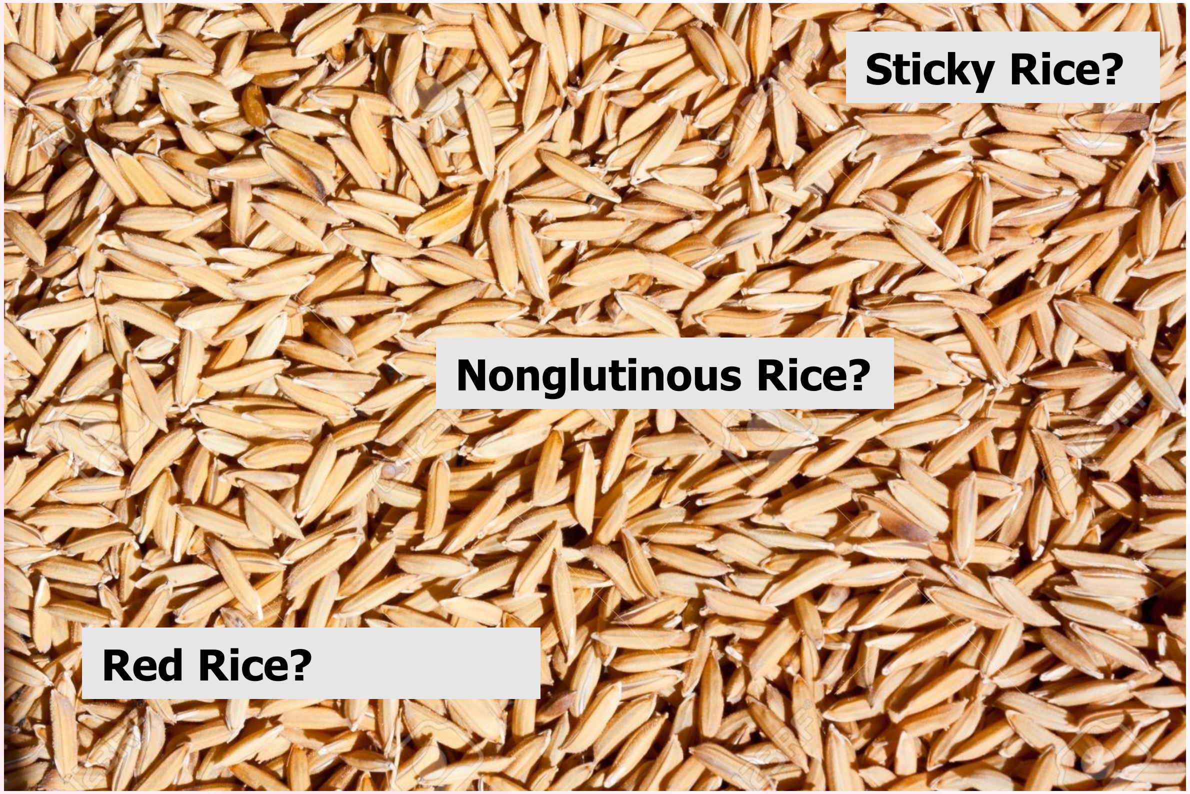




Key features:

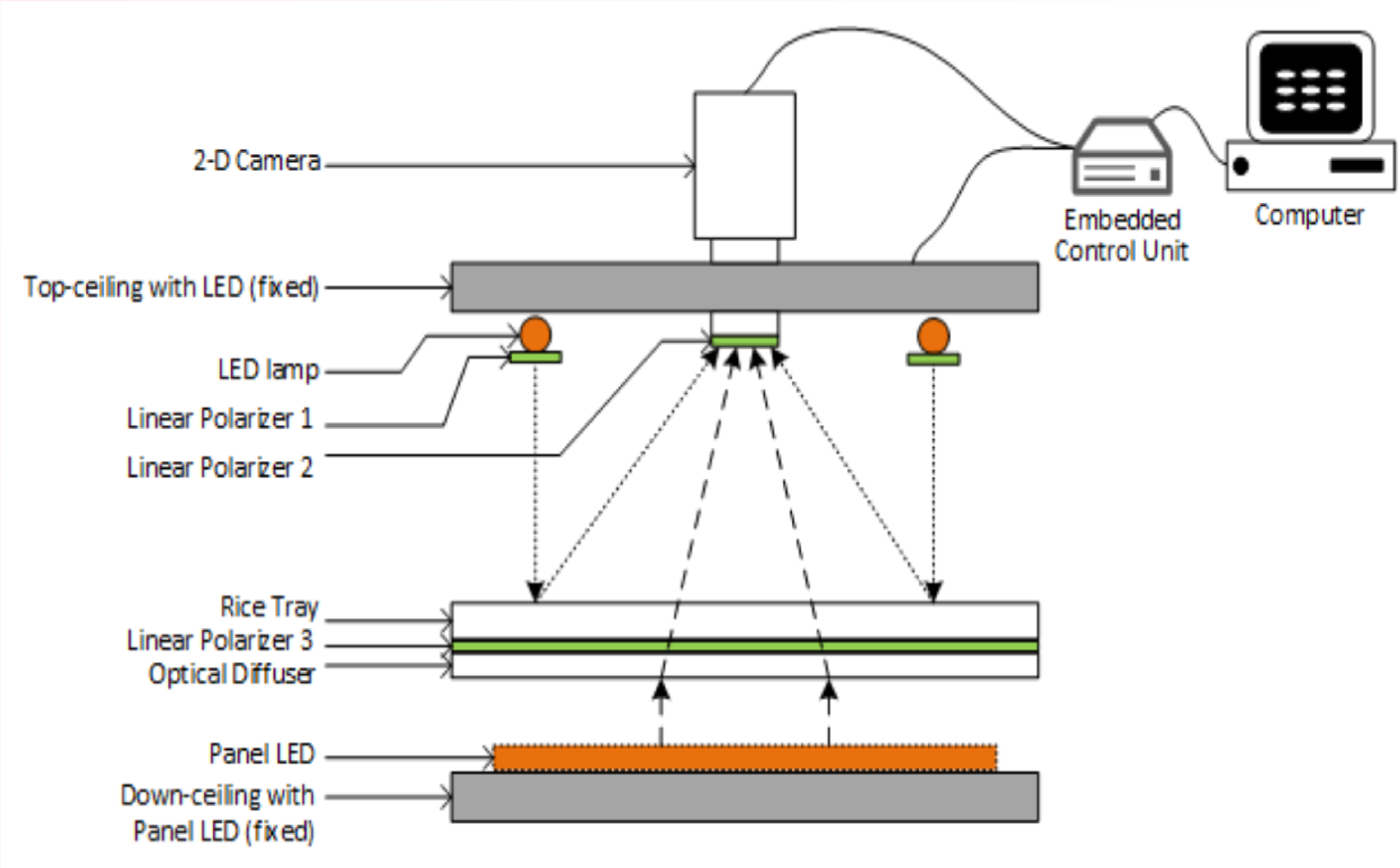
- Simultaneous analysis of width, length, thickness of rice grains
- Simultaneous analysis of width, length, and thickness of rice seeds
- Fast and high accuracy
- *Future analysis relates to Yellowish and Chalkiness of Rice Grains*

- **Unwanted sticky and red rice seeds in non-glutinous rice seeds**

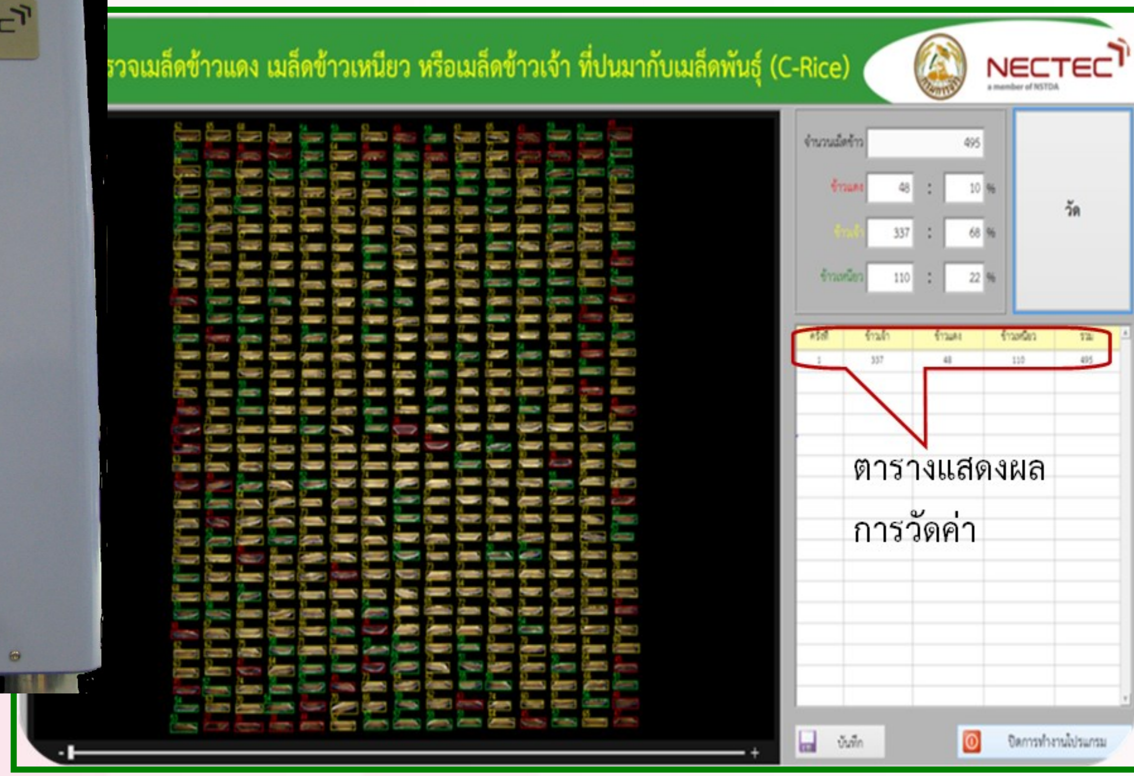


Analyzes Light Passing through Rice Seeds

Proposed Solution



C-Rice: *Rice Seed Quality Analyzer*

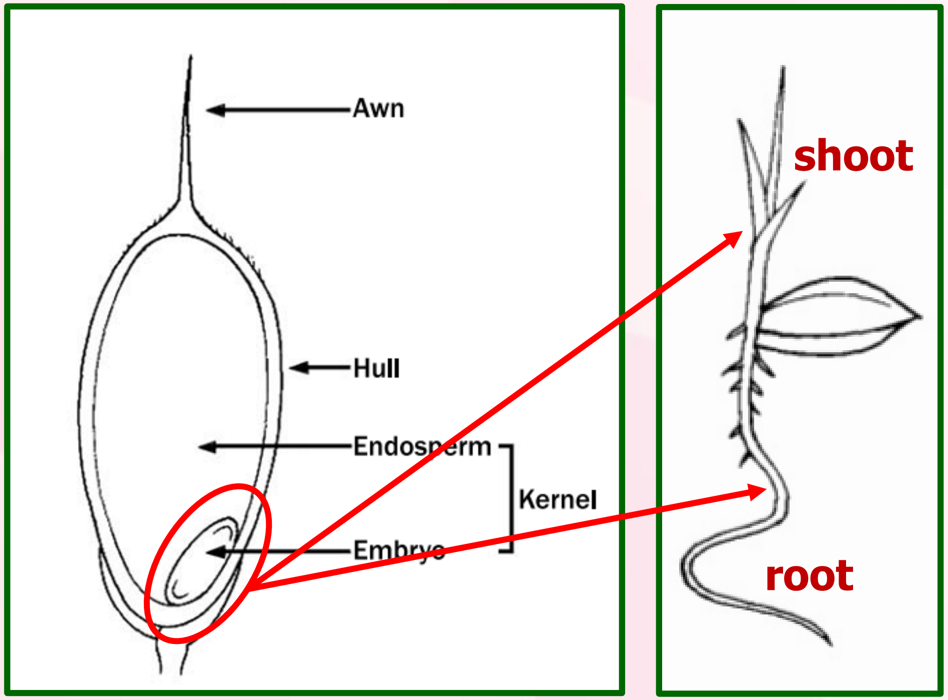


Key features:

- Identification of non-glutinous rice seeds from unwanted sticky and red rice seeds
- Fast and high accuracy

- **Size of Embryo/Endosperm**

Embryo: The shoot and the root parts of a seedling
Endosperm: Food needed for germination



Physical Dimensions are related to Healthiness of Seedling and Nutrition

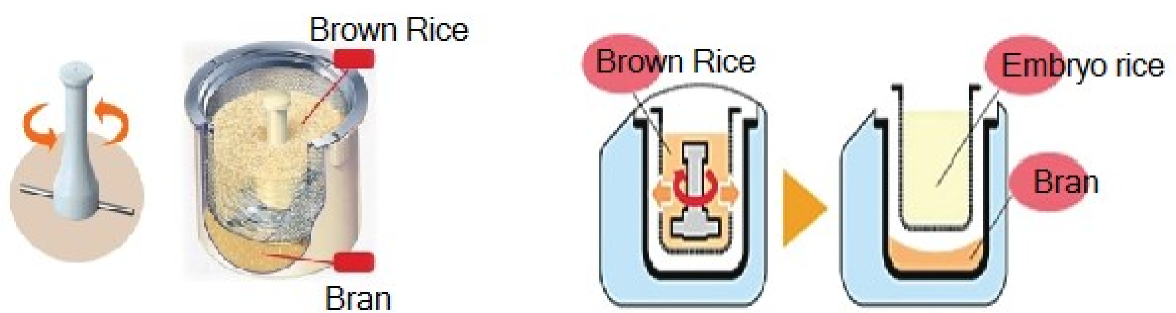
Nutrition -> **Embryo:** protein, fat, dietary fiber, vitamins, and minerals
Endosperm: starch (almost 80%), sugar, protein, and fat

Destructive Approaches

By hands then manually measuring

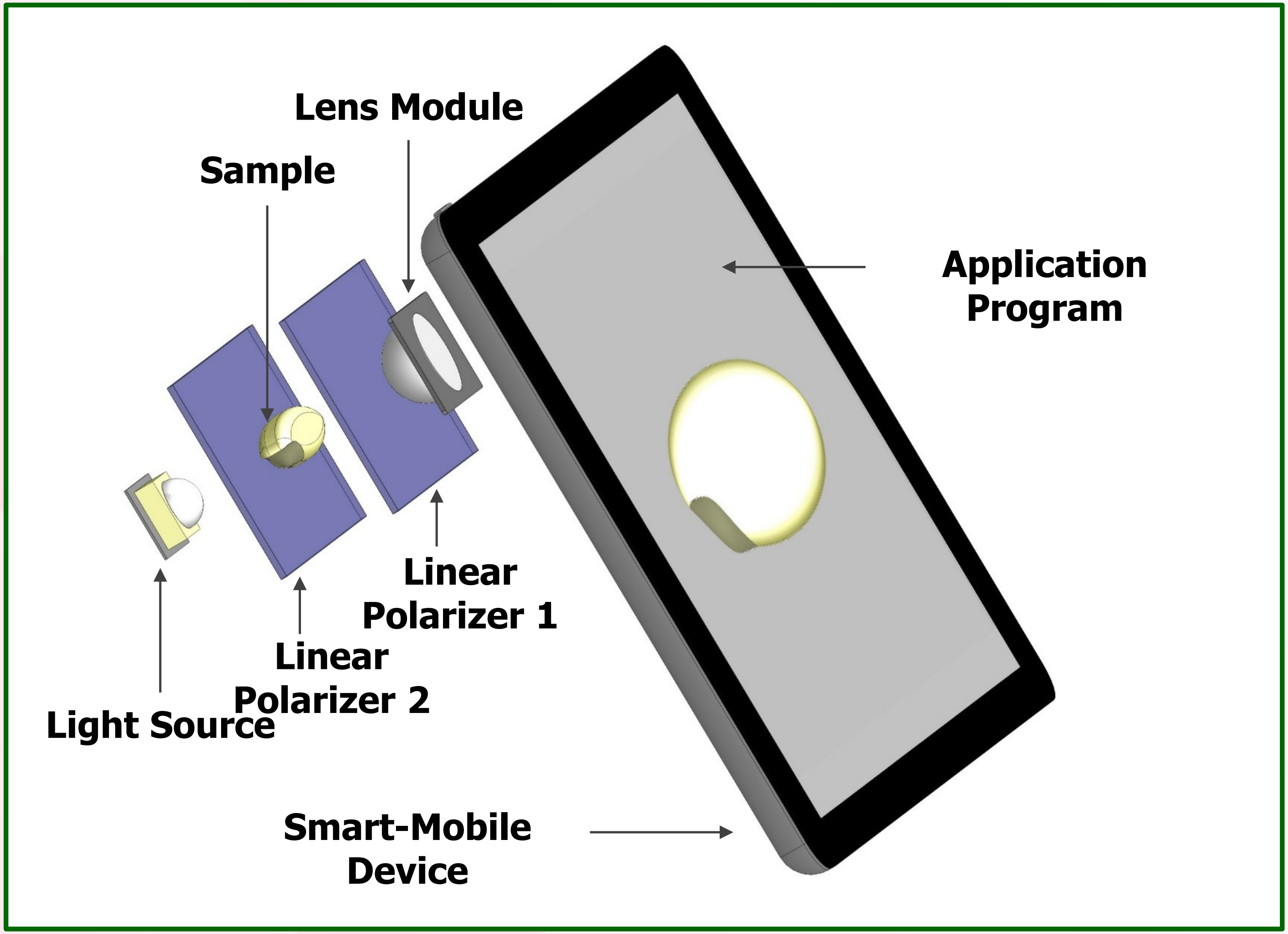
J. Cereal Sci. 59, 211–218 (2014)

By machines then manually measuring



http://eujime.com.my (2014)

Proposed Arrangement of a Two-Dimensional Embryo Area Estimator



Proposed Processing Steps

for separating and analyzing embryo and endosperm areas

Rice Color Image

↓

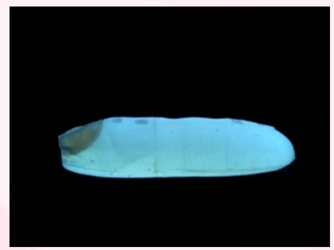
Blue Plane Image

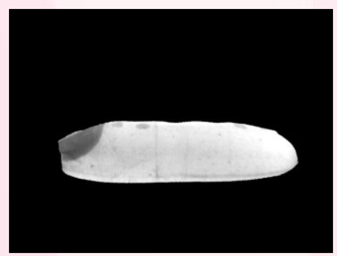
↓

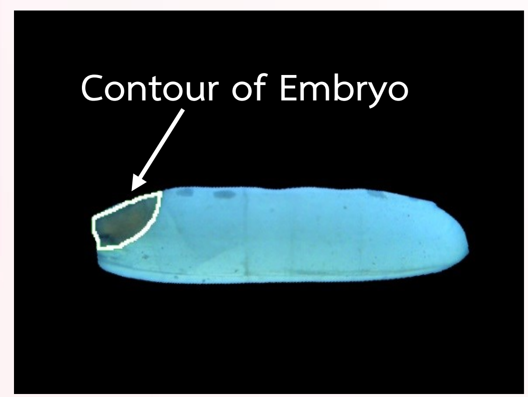
Thresholding Method

↓

Blob Analysis Method

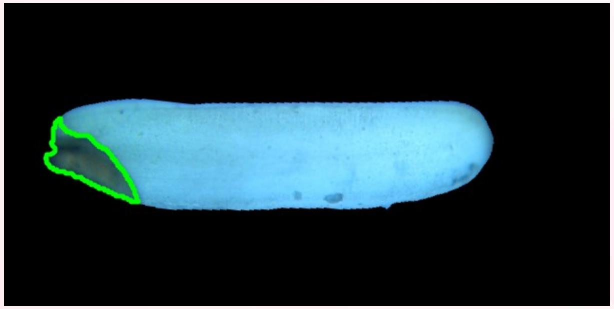




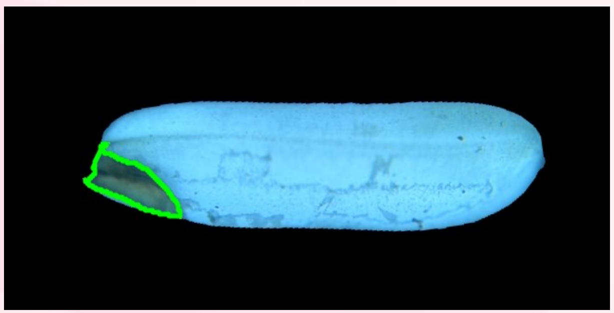


The Result of Automatic Measurement

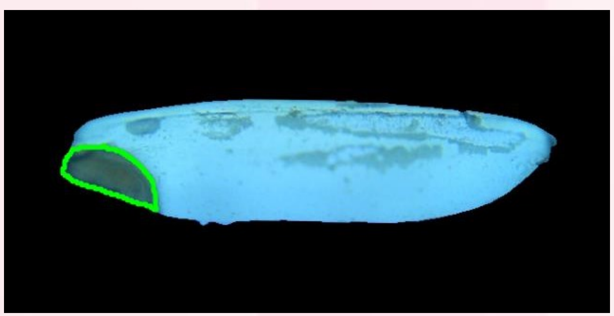
KDML 105



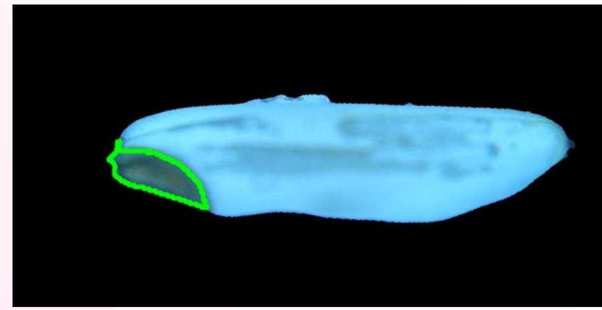
PSL 2



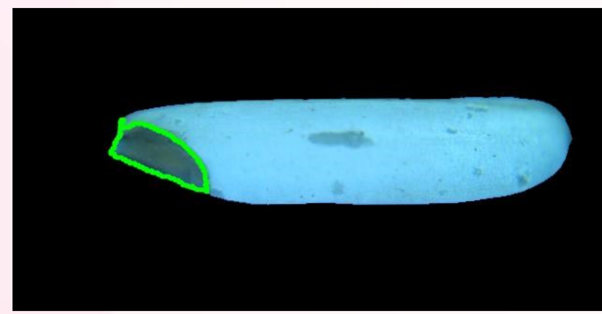
RD 47



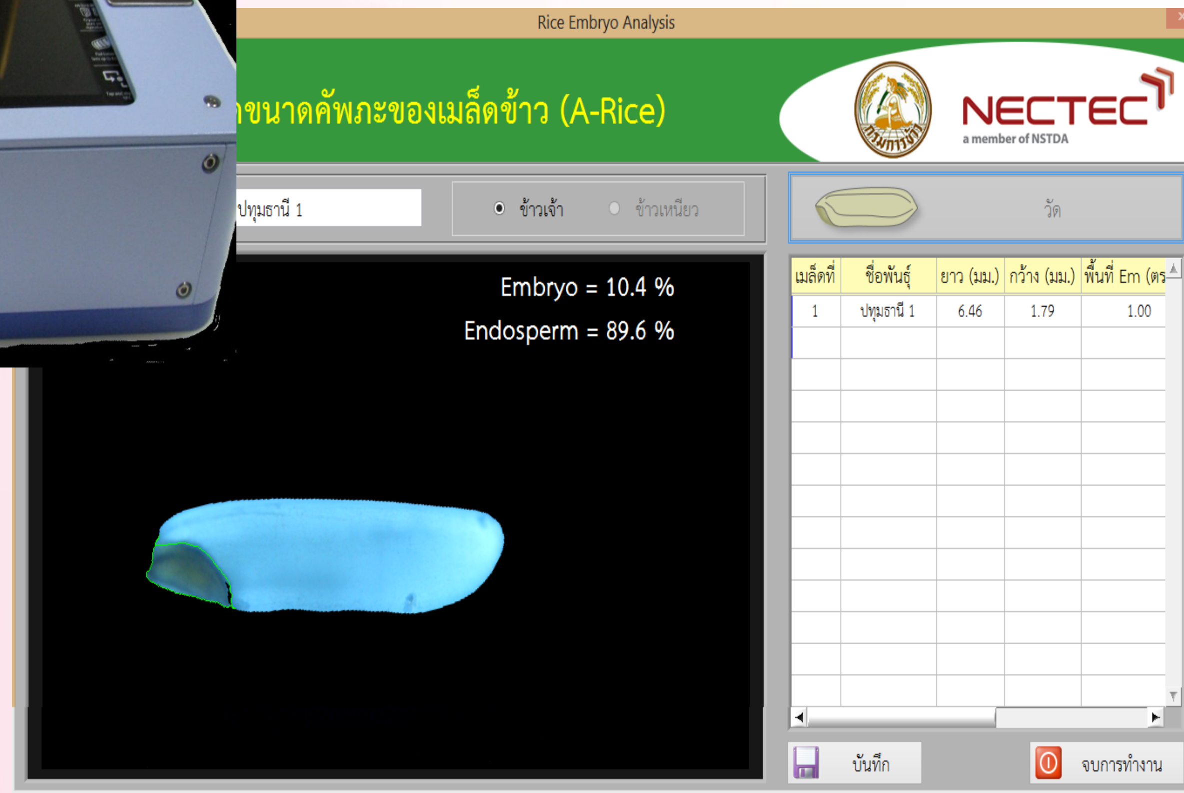
PTT 1



RD 41



A-Rice: *Rice Embryo Analyzer*



Key features:

- Area analysis of the embryo and endosperm
- Fast and high accuracy

Y. Intaravanne, S. Sumriddetchkajorn, K. Chaitavon, S. Chanhorm, P. Pongsoon, and A. Prasertsak, *Proc. SPIE*, Vol. 9273, pp. 92730T, Beijing, China, October. 2014.

Result Comparison between Manual Measurement and Our Prototype

Rice Variety	Manual Measurement			Our Approach			%ΔEm	%ΔEn
	%Em	%En	STD	%Em	%En	STD		
KDML 105	6.6	93.4	1.09	7.1	92.9	1.90	7.9	0.6
PSL 2	6.4	93.6	1.28	6.4	93.6	1.33	0.0	0.0
PTT1	7.4	92.6	1.56	6.8	93.2	1.93	8.3	0.7
RD 47	6.9	93.1	1.48	7.4	92.6	1.55	6.9	0.5
RD 41	7.8	92.2	1.66	8.1	91.9	1.72	4.1	0.3

%Δ = |(Manual-Auto)|×100/Manual
%Em = The percentage of embryo area
%Em = The percentage of endosperm area

Error < 9%.

Causes of Error

- **Fragment tissues left:** they looks like the embryo area under our proposed approach
- **Change of orientation of rice grain:** image contrast is reduced

Conclusion

NECTEC
a member of NSTDA

With examples of Real Needs

- Nitrogen (N) Deficiency Issue
- Unwanted Mixture of Rice Varieties
- Quality Control of Rice Seeds and Grains

Optical imaging/sensing can answer

To make the ideas/concepts practical

Photonics

Electronics

Computer Science

Prototype Design

UI/UX

Biology

Mechanics

Chemistry