

EARLY STAGE GASTRIC CANCER DETECTION IN MAGNIFIED NBI ENDOSCOPY IMAGES

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2013/07/04 Osaka Japan

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2014/04/26 YunTech Taiwan



2015/12/05 Taipei

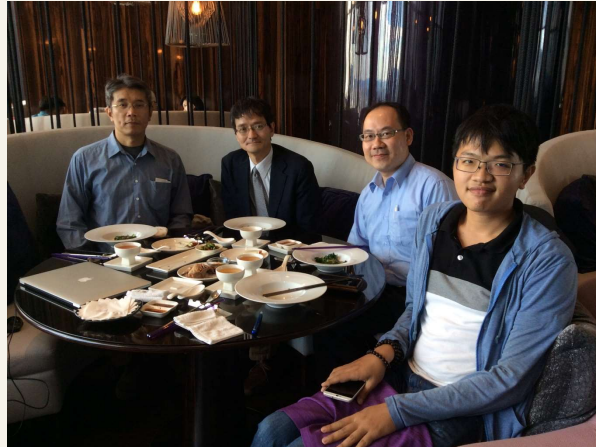


Image Enhanced Endoscopy (IEE)

- Encompass various means of **enhancing contrast** during endoscopy using **dye, optical, and/or electronic** methods
- Examples:
 - **Narrow band imaging (NBI)**
 - **Autofluorescence imaging (AFI)**



Narrow-Band Imaging (NBI)

The diagram illustrates the NBI system. A Xenon Lamp emits light that passes through an NBI filter. The filter can be turned OFF (allowing broad-spectrum white light) or ON (allowing only specific narrow-band wavelengths). When ON, the light passes through an RGB Rotary Filter. The resulting narrow-band image highlights the mucosal surface, which is rich in blood vessels. The diagram also includes a graph of the Hb absorption curve, showing peaks around 415 nm and 760 nm, and a graph of the RGB broad band spectrum, showing peaks around 450 nm, 510 nm, and 610 nm. The white light image shows a broad spectrum of light, while the narrow band image shows a specific wavelength range.

White light image (RGB broad band)

Narrow band image

Hb absorption curve

White light

NBI

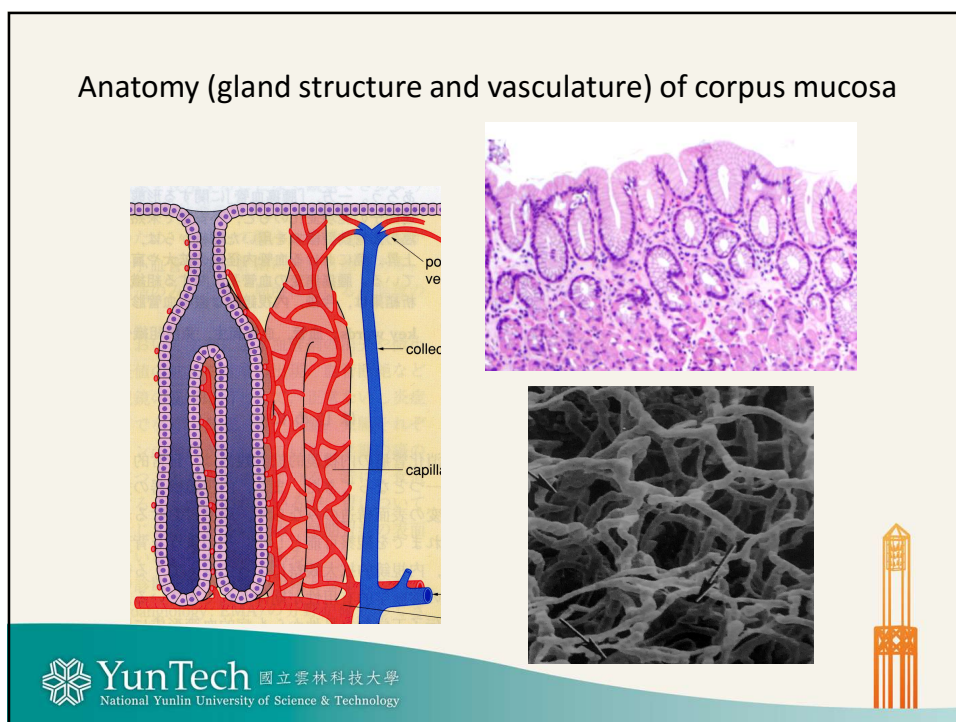
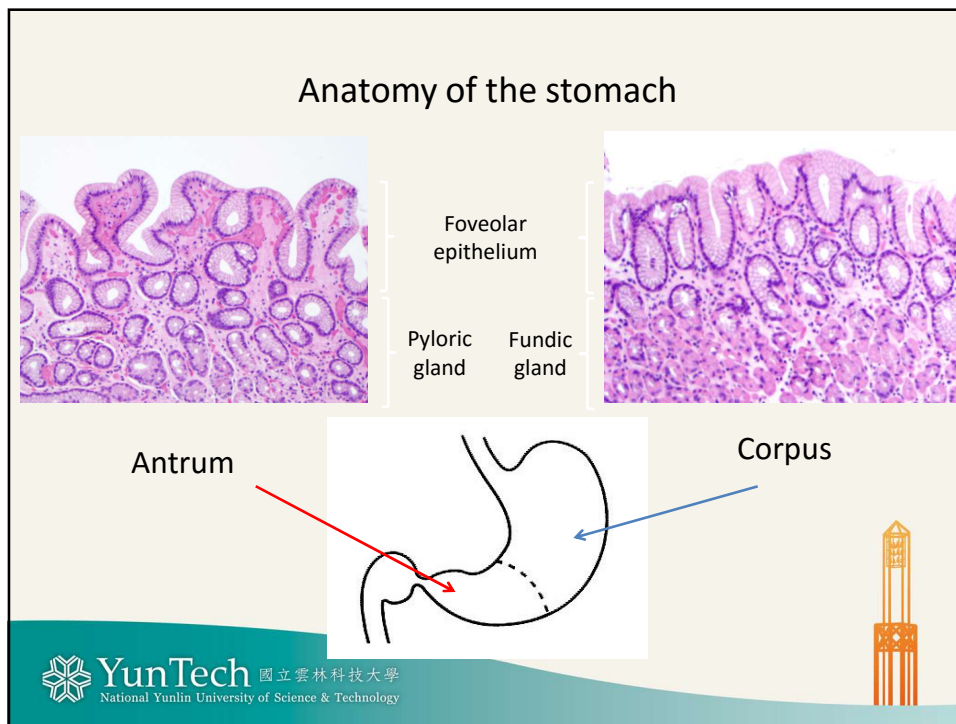
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NBI image of gastric mucosa

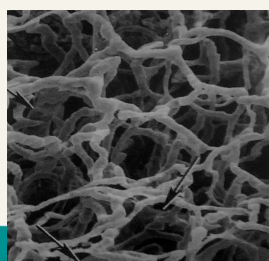
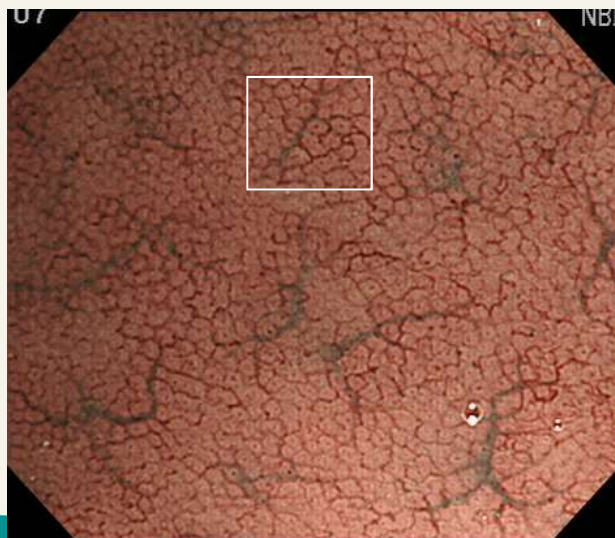
The image shows two side-by-side endoscopic views of the gastric mucosa. The left image is a white light image, showing the mucosal surface with some reddish areas. The right image is an NBI image, showing the same area with enhanced contrast, highlighting the mucosal surface and the underlying blood vessels.

- NBI filter cuts the light other than the specific wavelength:
- Gastric mucosa is rather rich in blood vessels

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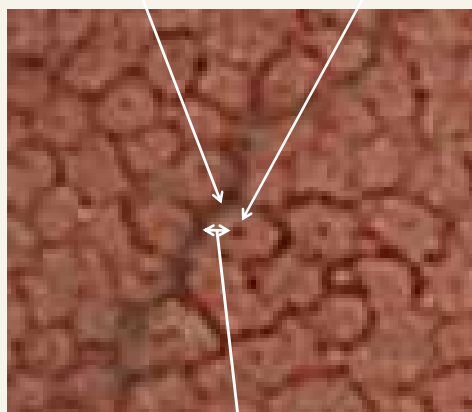


Magnifying NBI images of *H. pylori* negative **corpus** mucosa



Subepithelial capillary

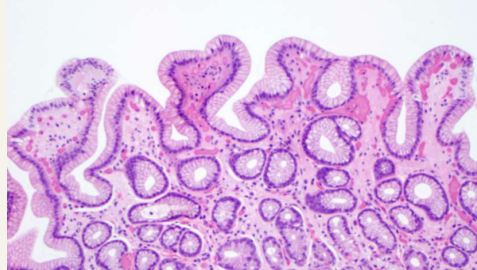
Gastric pit



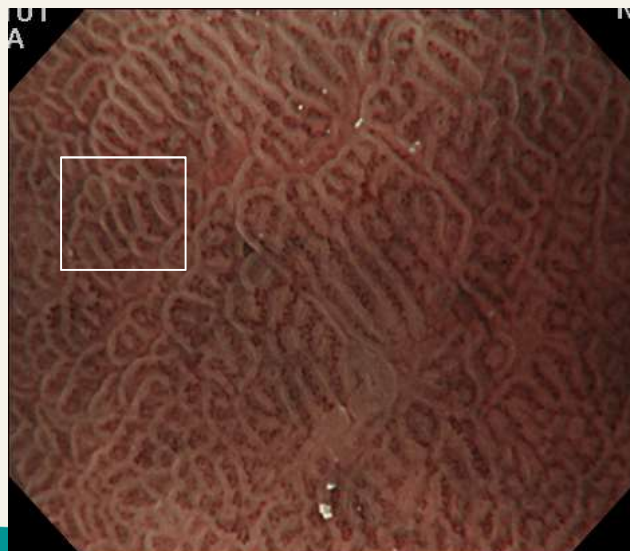
Marginal crypt epithelium

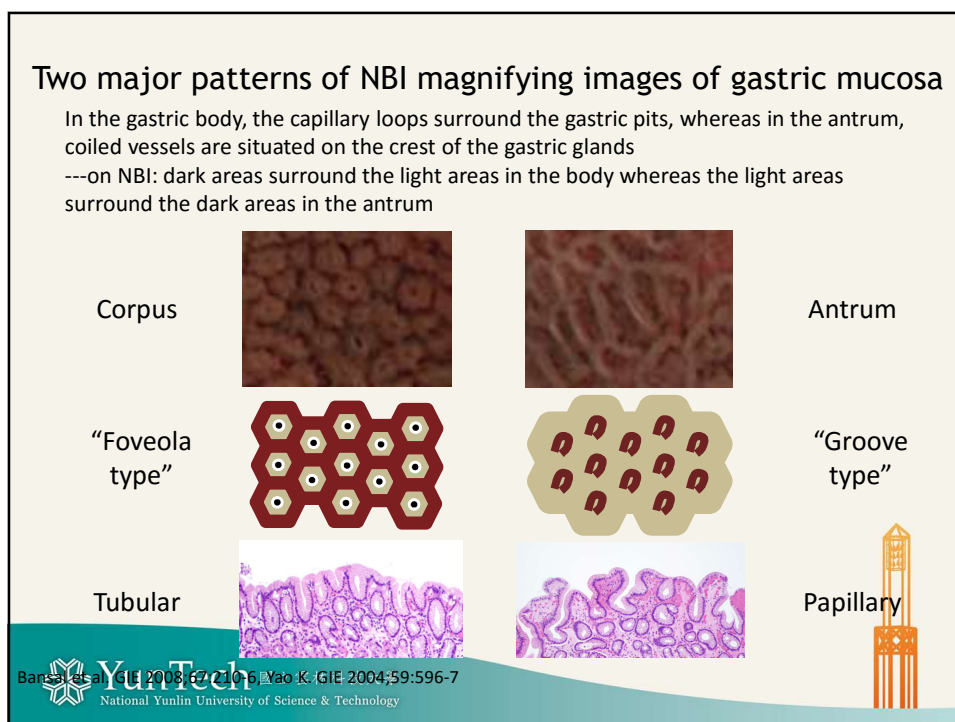
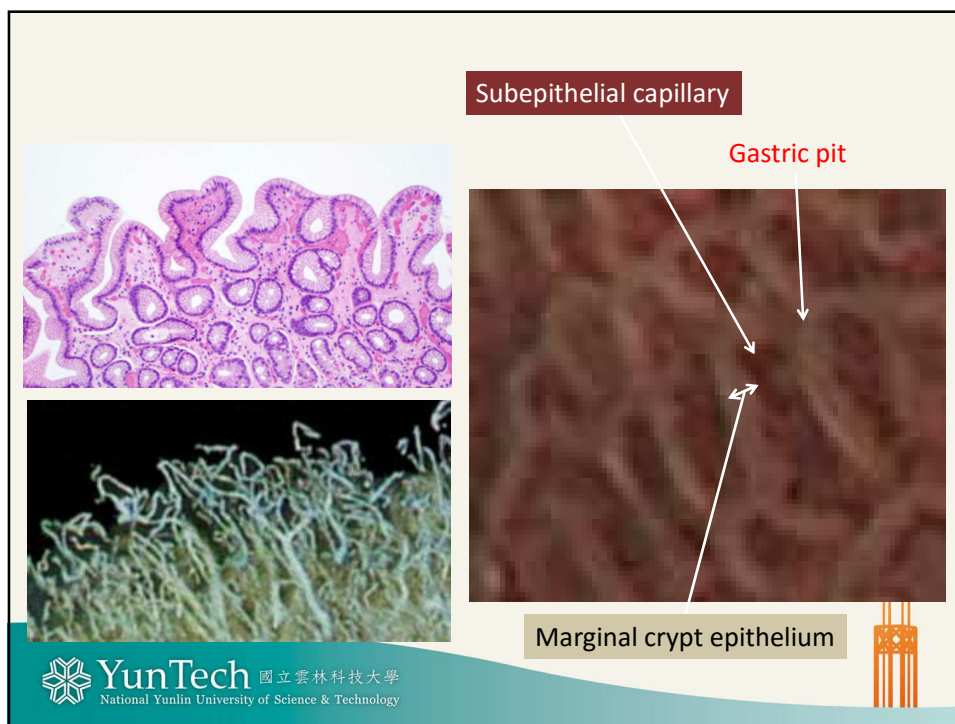


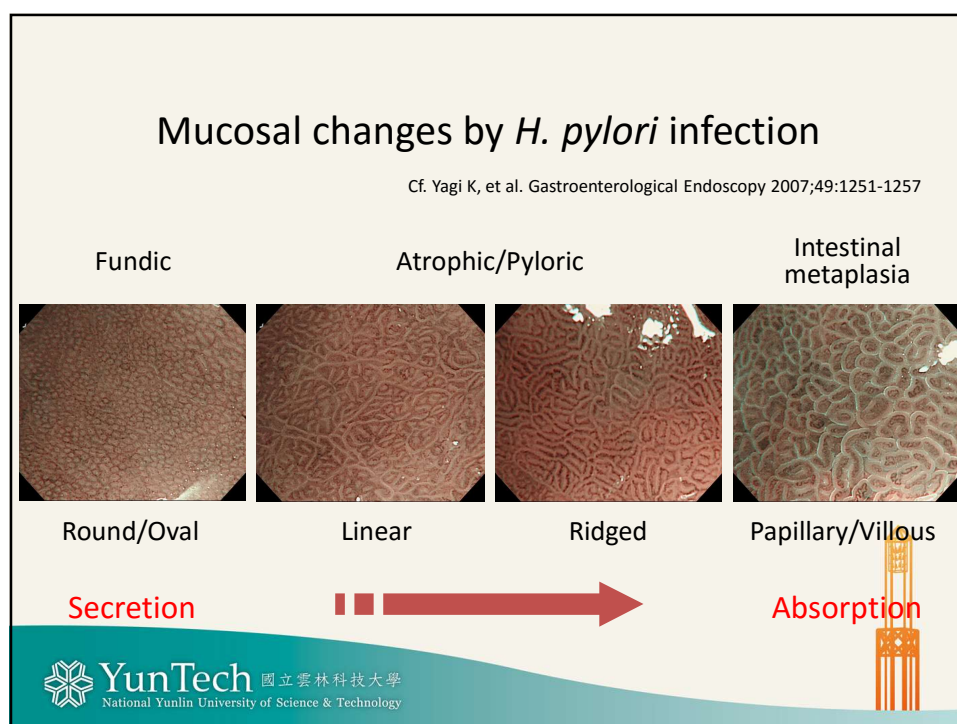
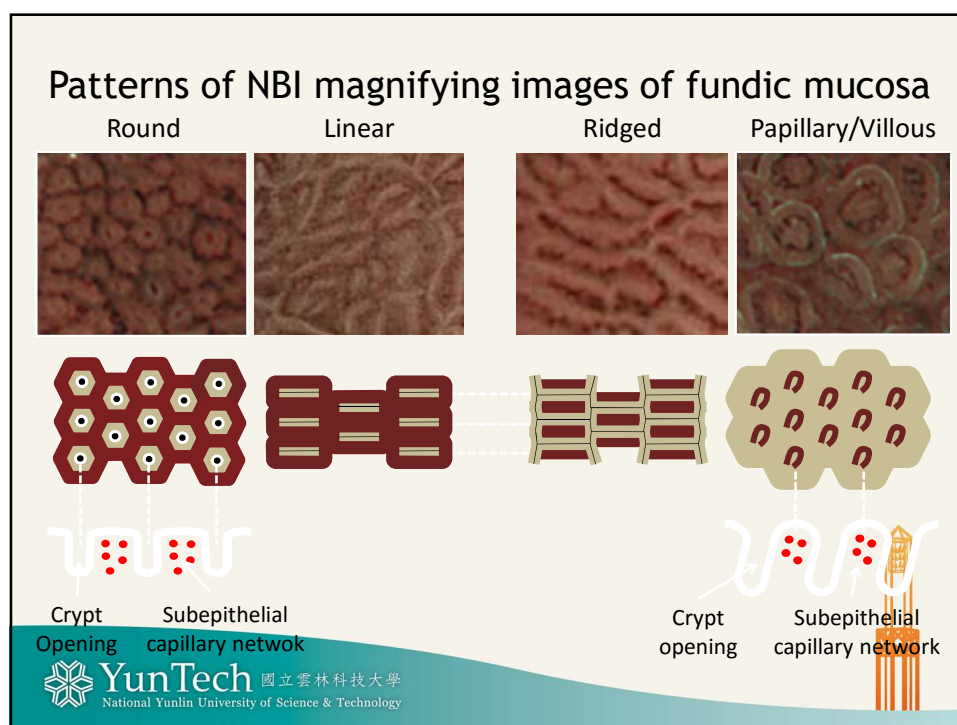
Anatomy (gland structure and vasculature) of **pyloric** mucosa

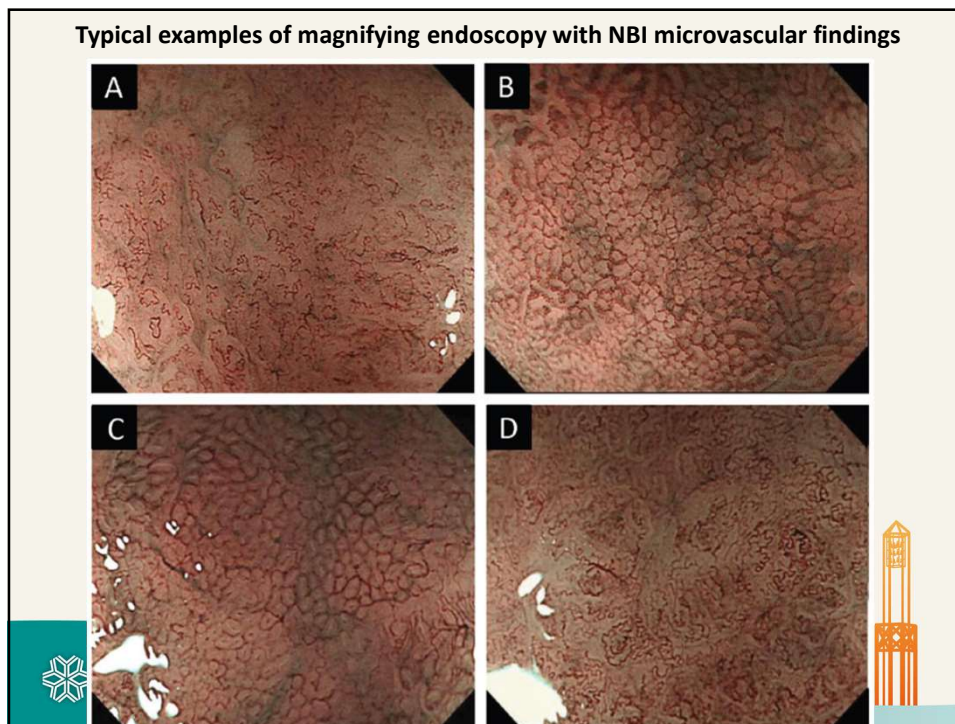


Magnifying NBI images of *H. pylori* negative **pyloric** mucosa





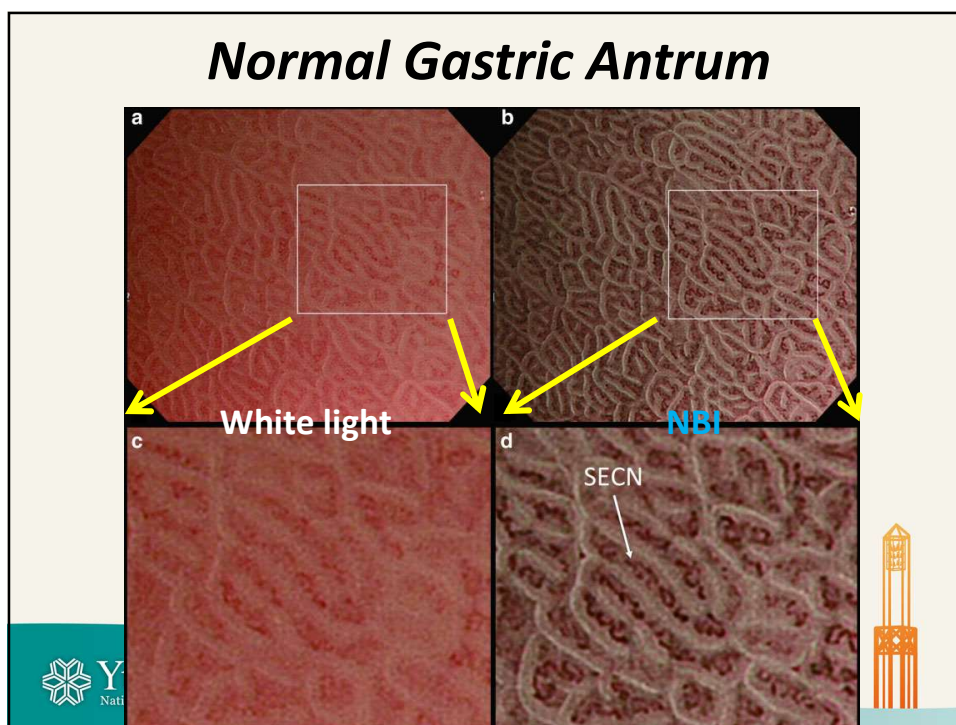
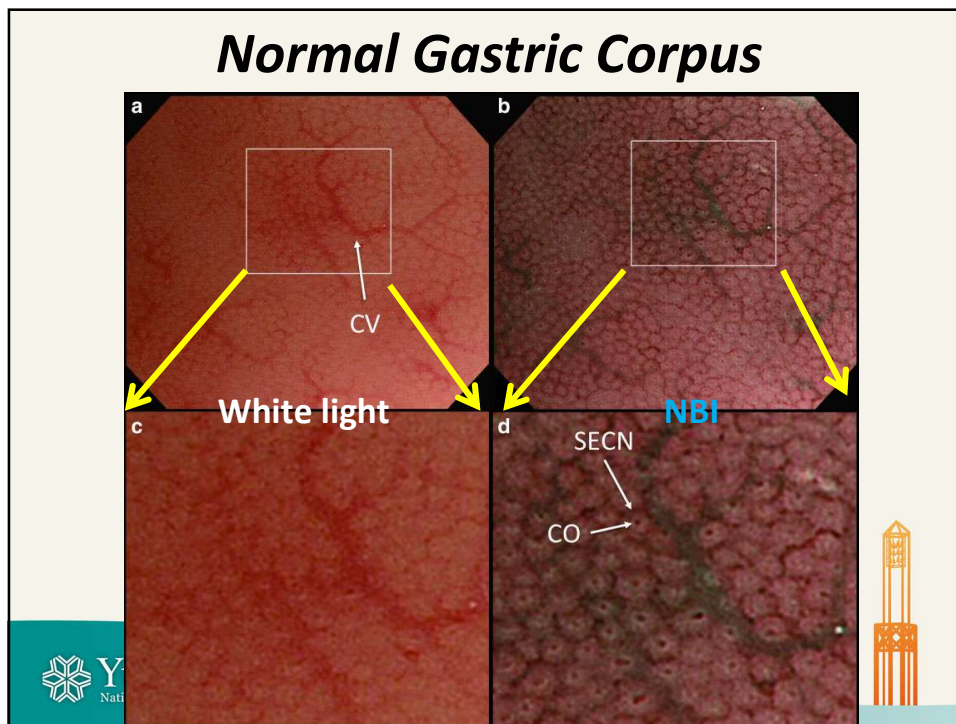




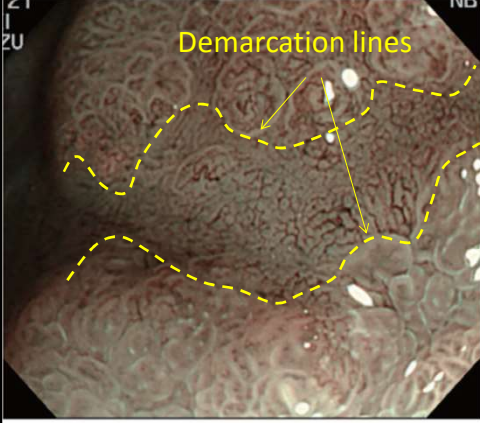
Magnified NBI Images

- Magnification: X 80-100 maximum
- A convenient adjunct to evaluate risk for developing gastric cancer
- Visualize distribution and characteristic of gastric premalignant condition



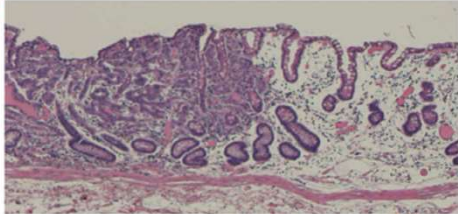


Characteristic findings of early gastric cancer in a magnified NBI image



Demarcation lines

- Microvascular pattern
Irregular/Regular/Absent
- Microsurface pattern
Irregular/Regular/Absent
- Demarcation line
Present/Absent

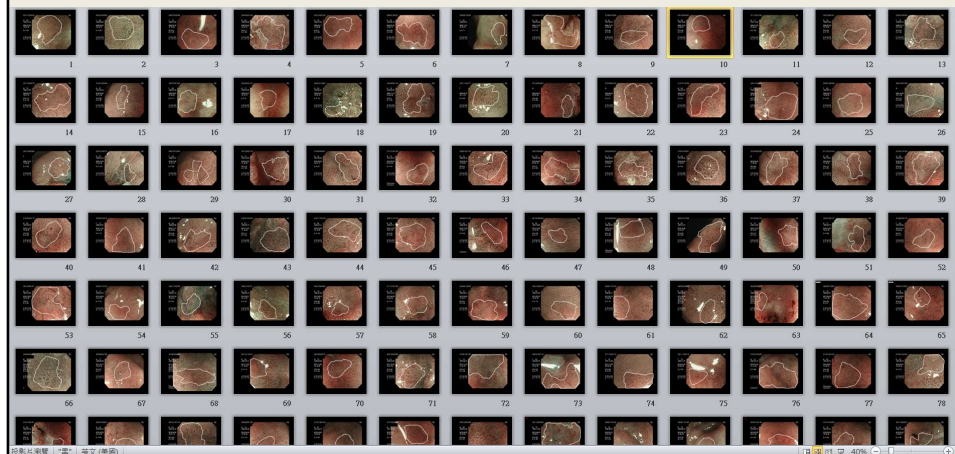


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Goal

- Develop **computer algorithms** to detect early stage cancer during gastroscopy operation
 - Based on collected magnified NBI images
 - Refer to
 - Extracted features in training examples
 - Rules/criteria defined by well-experienced doctors
 - System design and hardware implementation

Collected Images

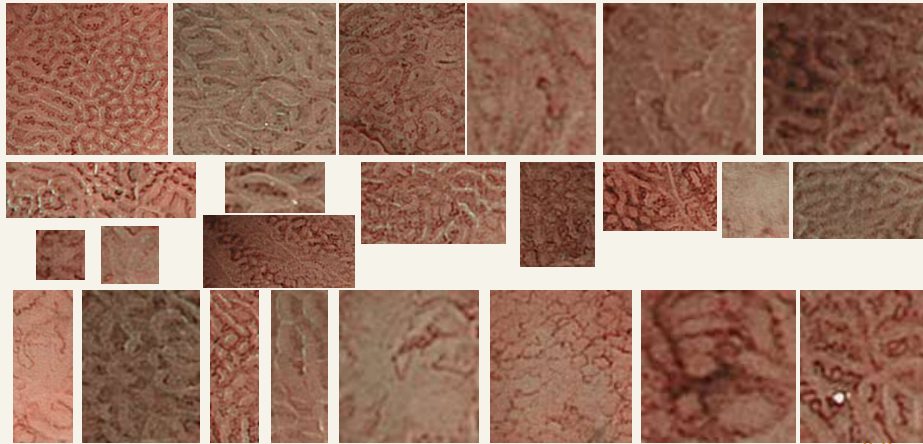


First Thought

- **Machine learning** based algorithms
 - Training with positive and negative examples
 - Features extraction from segmented image blocks
 - Classifier design



Sample Abnormal Lesion Patterns



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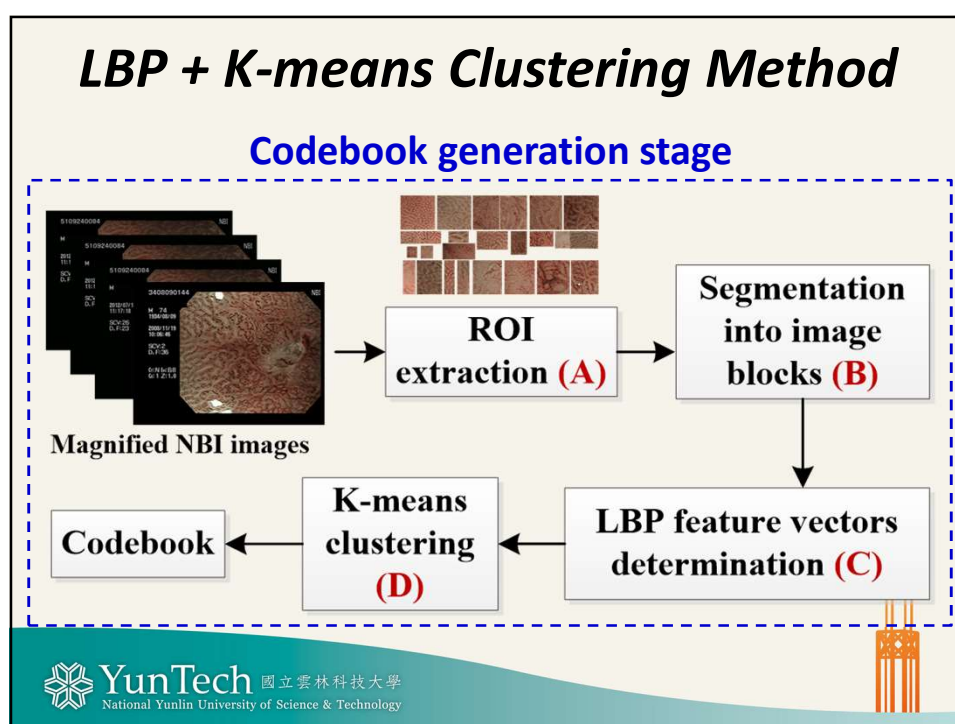
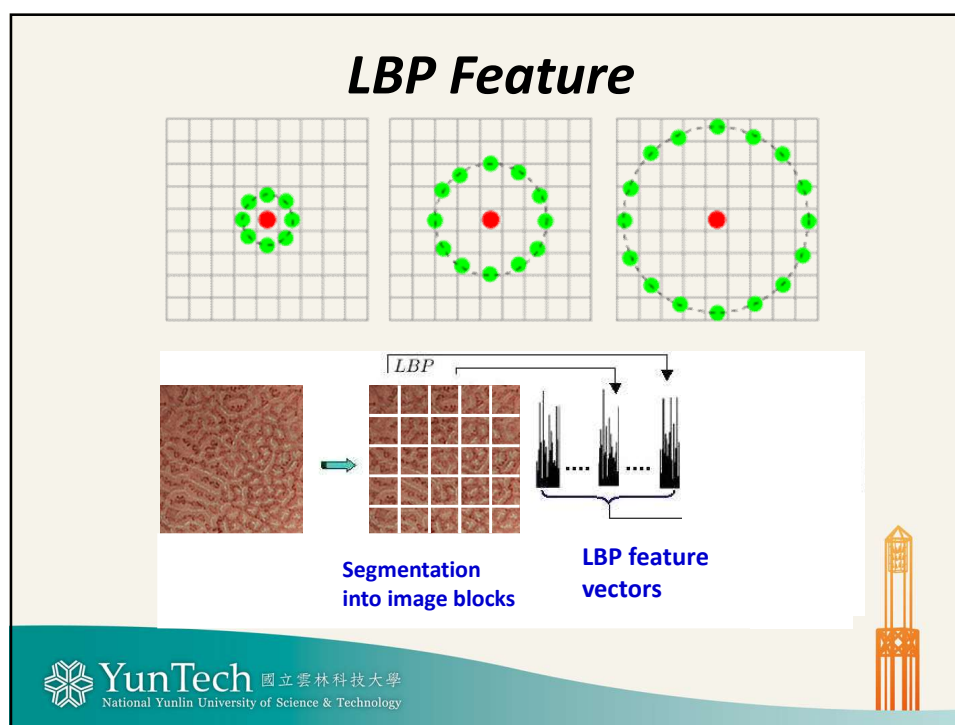
LBP Method

- ***Local binary pattern (LBP)*** is defined as a gray-scale invariant texture measure, derived from a general definition of ***texture in a local neighborhood***
- ***Robust to illumination variation, invariant to image rotations and contrasts***

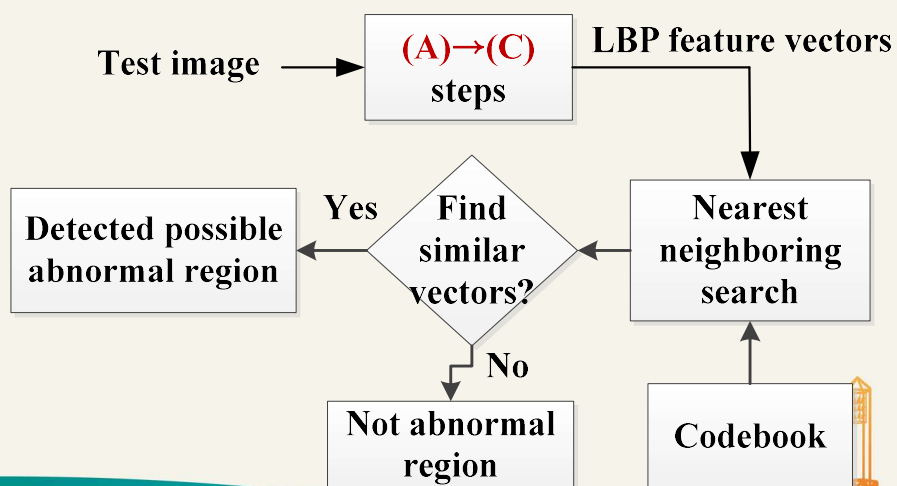


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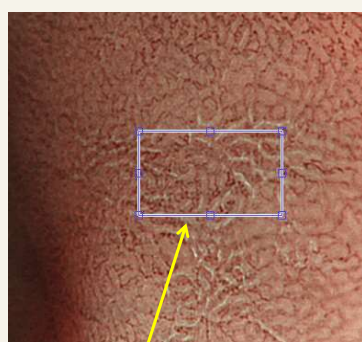


Block diagram for detecting possible abnormal region in test images

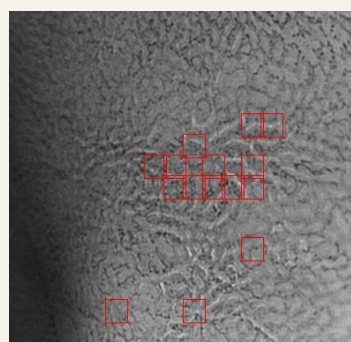


Result

Block size 25x25, LPB: $(R,P) = (1,8)$



Doctor's mark



System detected blocks

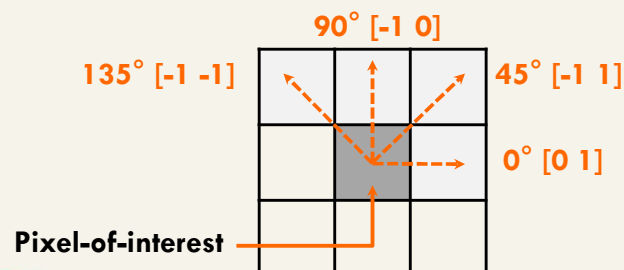
Conclusion on LBP Method

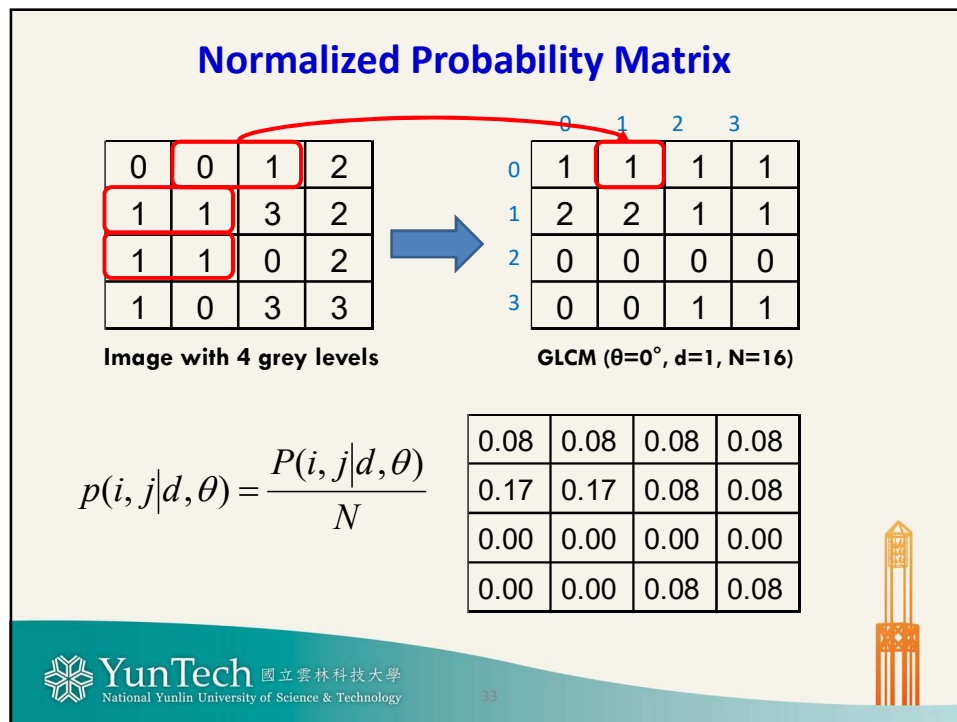
- Sensitivity is high, however, recall and precision rates are only 60%~70%
- Require fine tuning of system parameters
 - LBP parameters (R, P)
 - Block size, block segmentation, codebook size, threshold values



Gray-Level Co-occurrence Matrix (GLCM) Method

- A tabulation of how often different combinations of pixel brightness values (grey levels) occur in an image



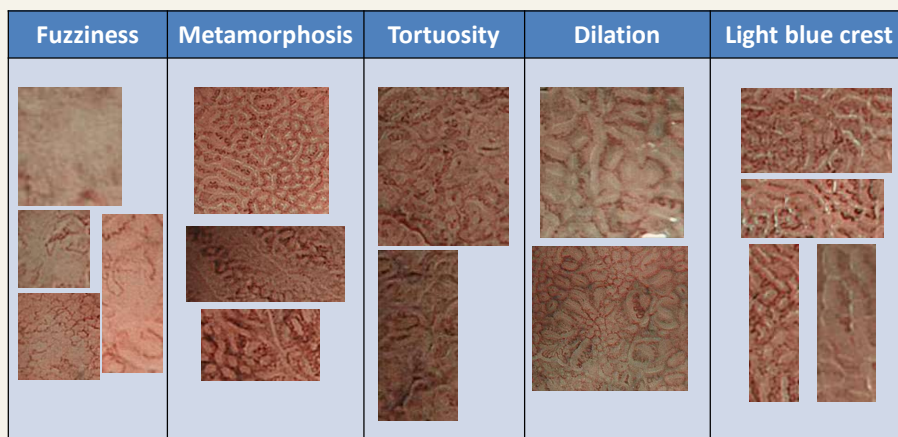


GLCM Features Determined From the Probabilities $p(i, j|d, \theta)$

- Block size 50 x 50
- $d=2$, $\theta = 0^\circ$ 、 45° 、 90° 、 135° 、 180° 、 225° 、 270° 、 315°
- Four features determined
 - Angular second-moment (ASM)/ Energy
 - Contrast
 - Correlation
 - Inverse difference moment (Homogeneity)

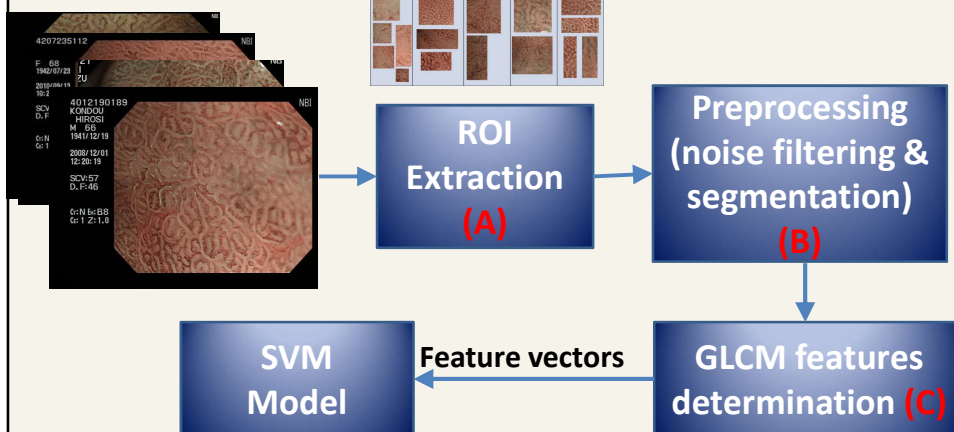


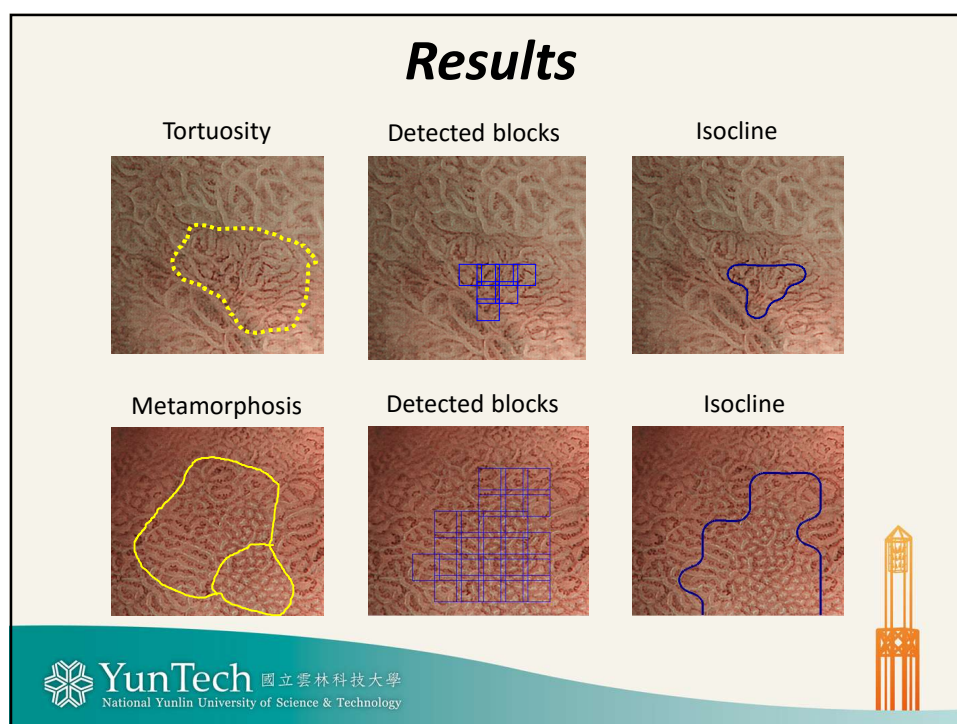
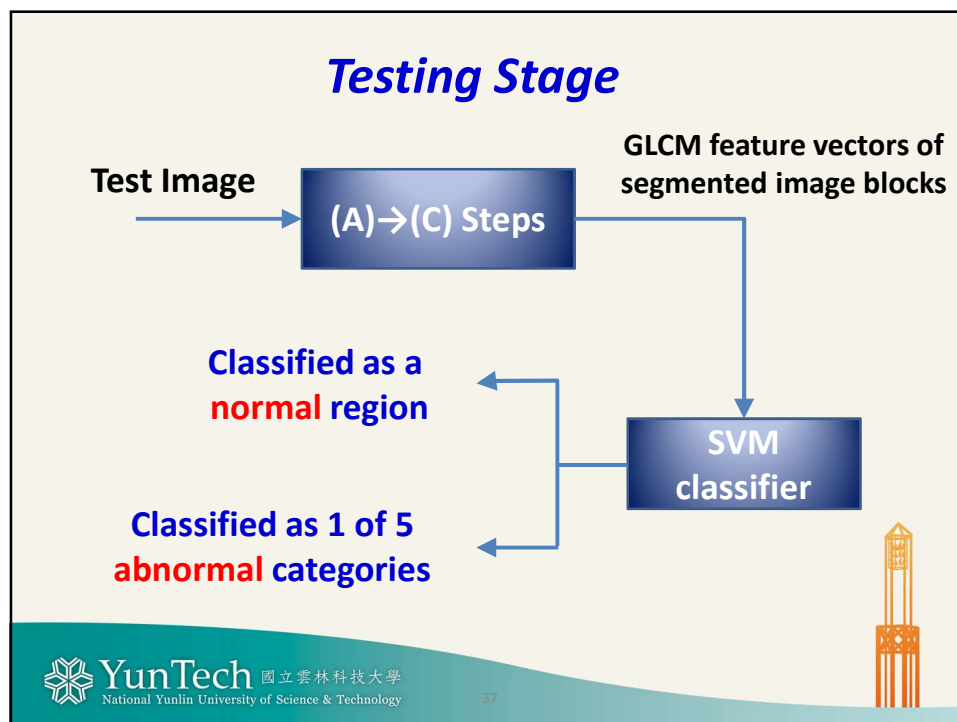
Five Categories in Abnormal Cases



System Diagram - Training stage

Classified Magnified
NBI images





Conclusion on GLCM Method

- Similarly, high sensitivity, but recall and precision rates are still not high enough (60~70%)
- Require fine tuning of system parameters
- Explore more GLCM features

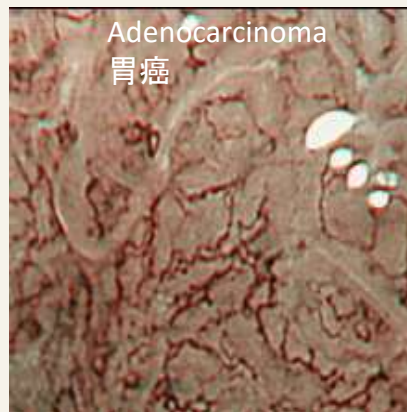


Current Strategy

- Use rules/criteria defined by well-experienced doctors or from the literatures
-
- Two major perspectives:
 - ***Microvascular architectures***
 - ***Microsurface Structures***



Characteristics of irregular microvessel pattern



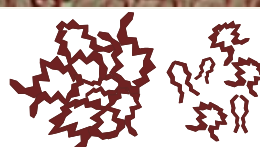
Dilation,
Tortuosity



Irregularity
of margin



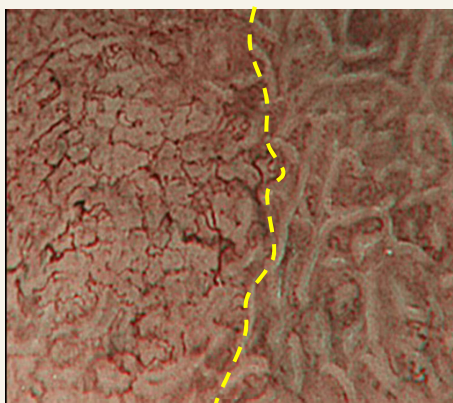
Difference
of caliber



Variation of shape,
size and orientation

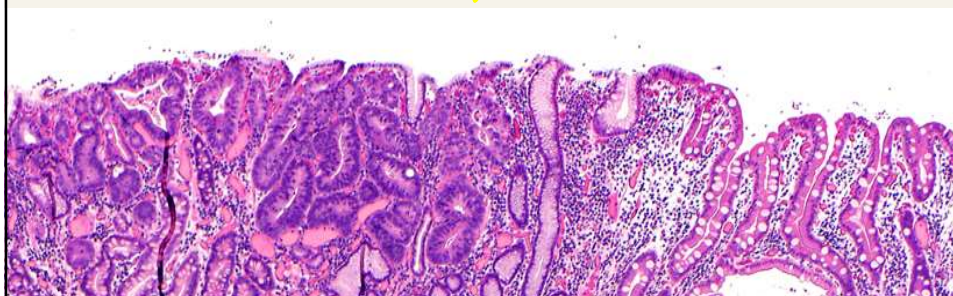
Tumor

- **Irregular** microvessel pattern
- **Absent** microsurface pattern
- **Demarcation line** present



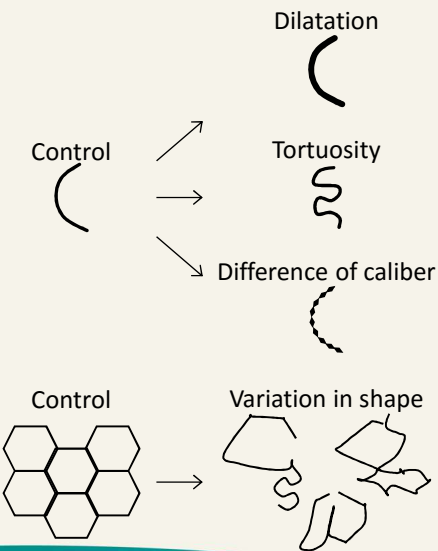
Background

- **Regular** microvessel pattern
- **Regular** microsurface pattern



Microvascular Architectures

Control



Dilatation

Tortuosity

Difference of caliber

Control

Variation in shape

1. **Dilatation:** Presence of a group of microvessels whose calibers are ≥ 1.5 times as wide as the calibers of reference microvessels.
2. **Tortuosity:** Presence of a group of microvessels which are twisted or bent.
3. **Difference of caliber:** Presence of a group of microvessels whose calibers abruptly become less than one half or more than double the original size.
4. **Variation in shape:** Presence of a group of microvessels whose shape and/or sizes are highly variable. In some cases, microvessels form polygonal loops whose shape and/or sizes are highly variable.

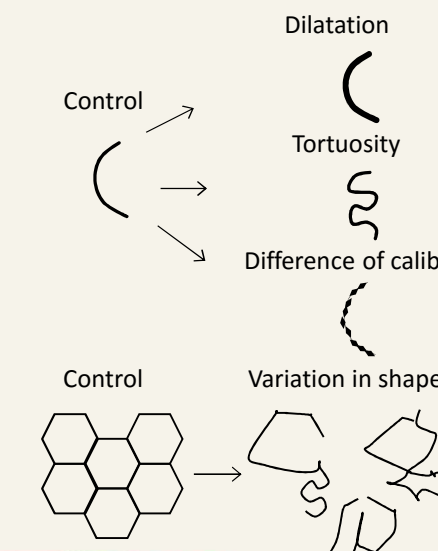


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Microsurface Structures

Control



Dilatation

Tortuosity

Difference of caliber

Control

Variation in shape

Irregularity of structure

1. **Dilatation**
2. **Tortuosity:** Presence of linear structure which are twisted or bent
3. **Difference of caliber:** Presence of a group of linear structure of that calibers abruptly become less than one half or more than double the original size
4. **Variation in shape:** Presence of a group of structure of that shape and/or sizes are highly variable

Absence of structure

1. **Disappearance** of structure



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Scoring

Microvascular architectures

Dilation
Tortuosity
Difference of caliber
Variation in shape

Microsurface structures

Dilatation
Tortuosity
Difference of caliber
Variation in shape
Disappearance

- (1) Present with high confidence
(2) Present with low confidence
(3) Absent
(4) Not evaluable.



Dilation & tortuosity in microvessels, disappearance of structures

5109240084

NBI

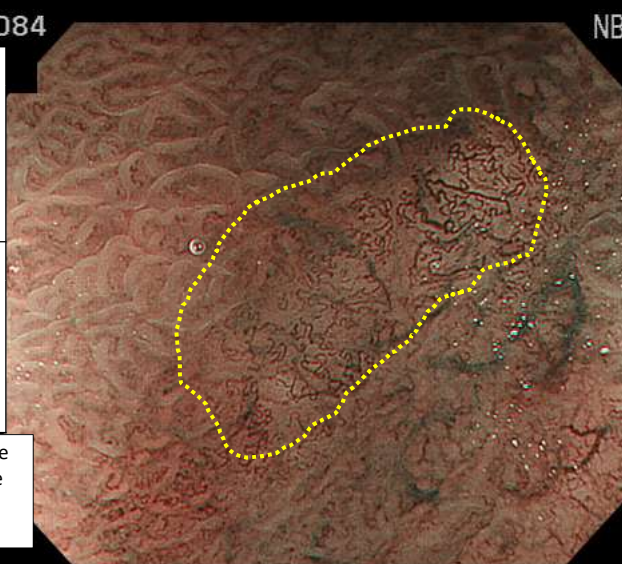
Microvascular architectures

Dilation **1**
Tortuosity **1**
Difference of caliber 3
Variation in shape 3

Microsurface structures

Tortuosity 4
Difference of caliber 4
Variation in shape 4
Disappearance **1**

- (1) Present with high confidence
(2) Present with low confidence
(3) Absent
(4) Not evaluable.



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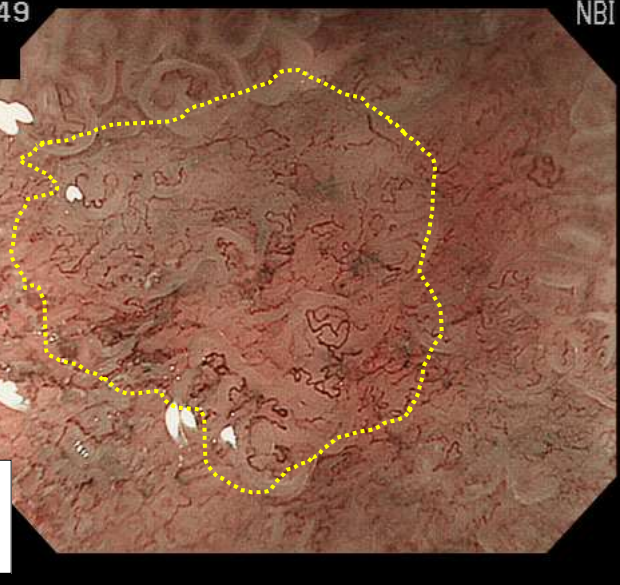
Variation in shape in microvessels, disappearance in structures

4407110149 NBI

Microvascular architectures	
Dilation	3
Tortuosity	3
Difference of caliber	3
Variation in shape	1

Microsurface structures	
Tortuosity	4
Difference of caliber	4
Variation in shape	4
Disappearance	2

(1) Present with high confidence
 (2) Present with low confidence
 (3) Absent
 (4) Not evaluable.



**Dilation & variation in shape in microvessels
Tortuosity in microsurface structure**

393 NBI

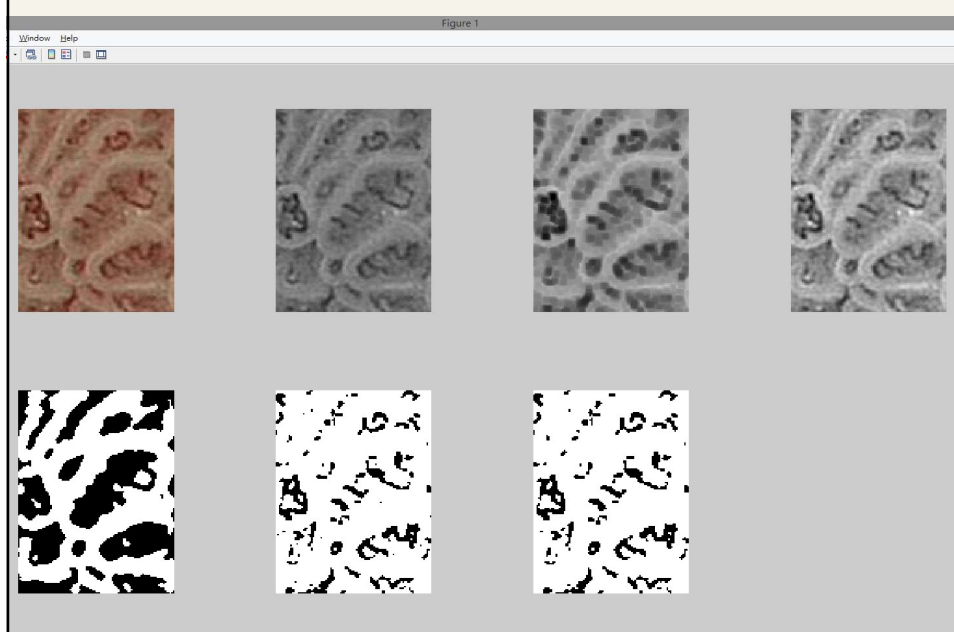
Microvascular architectures	
Dilation	1
Tortuosity	3
Difference of caliber	2
Variation in shape	1

Microsurface structures	
Tortuosity	1
Difference of caliber	3
Variation in shape	1
Disappearance	3

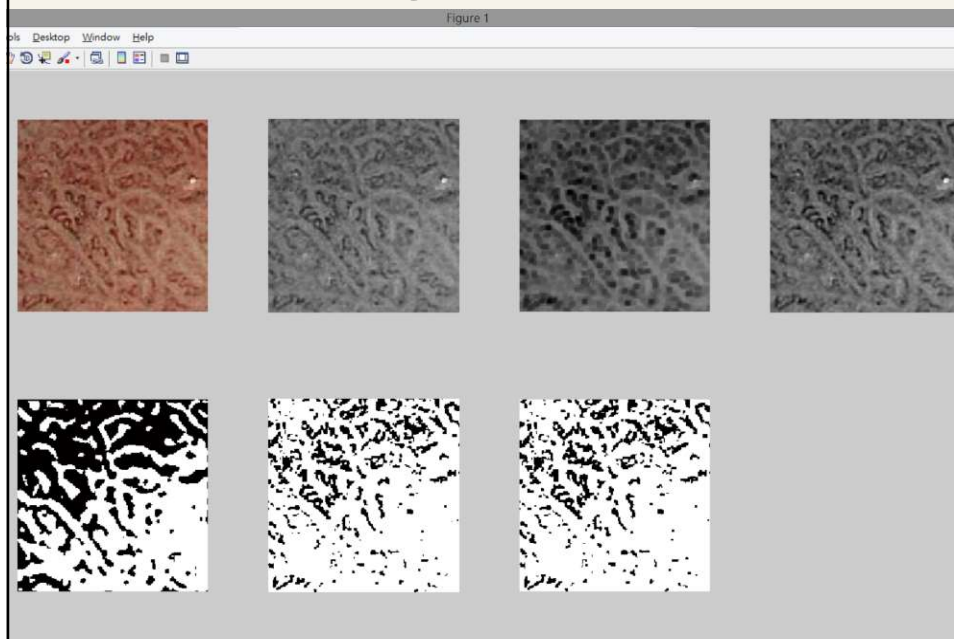
(1) Present with high confidence
 (2) Present with low confidence
 (3) Absent
 (4) Not evaluable.

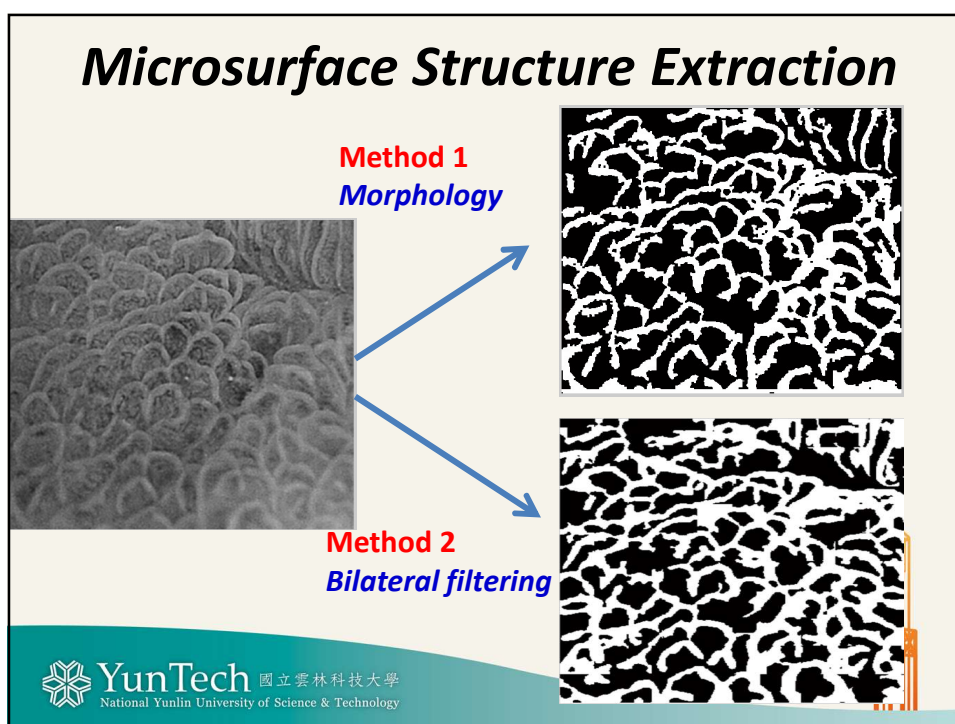
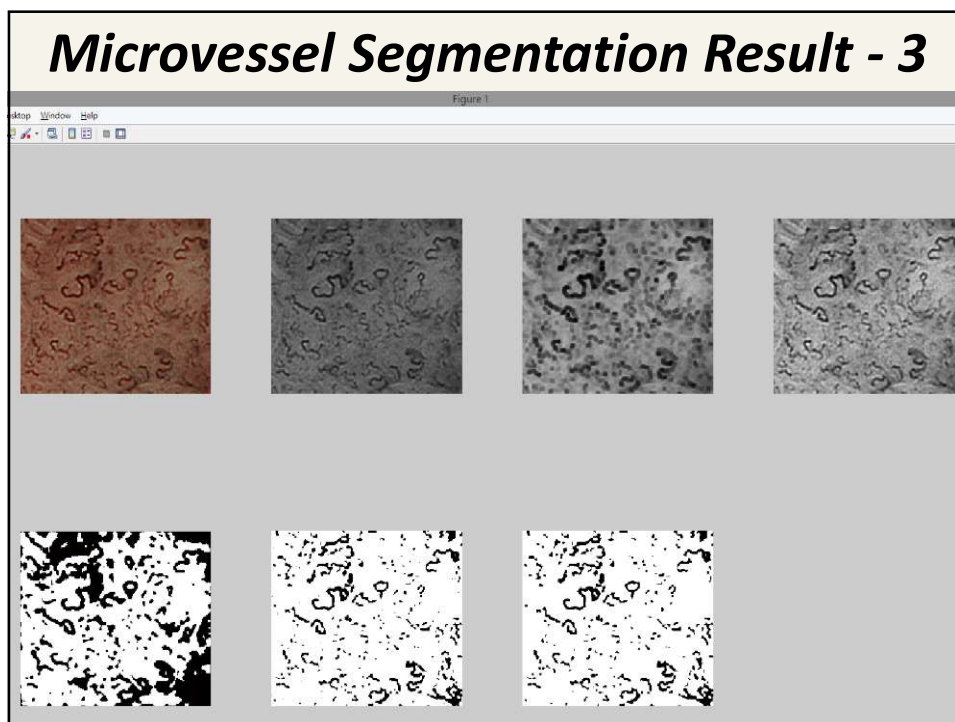


Microvessel Segmentation Result - 1

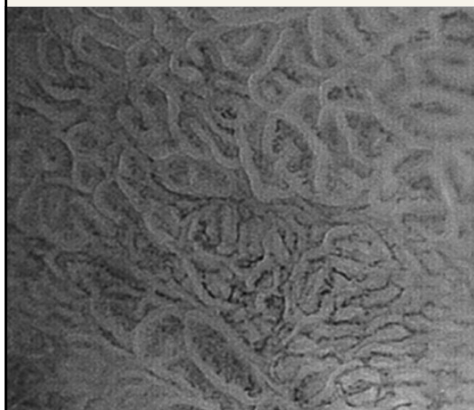


Microvessel Segmentation Result - 2

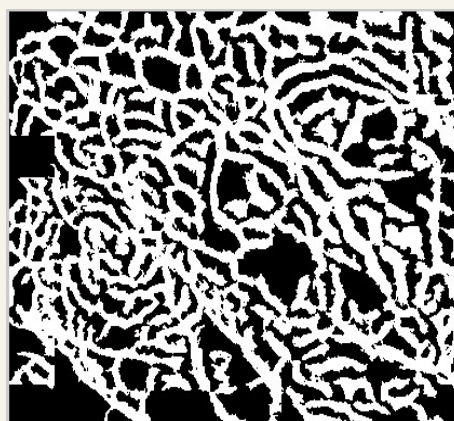
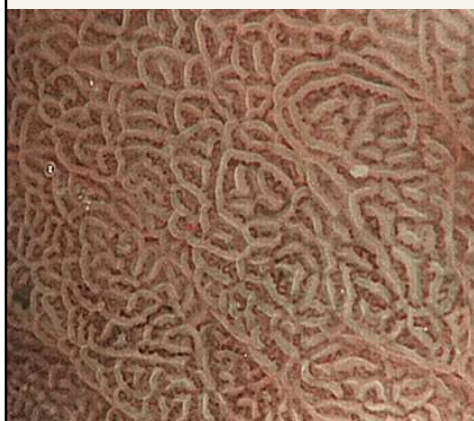




Microsurface Structure Example 2 (Method 1)



Microsurface Structure Example 3 (Method 2)



Ten structural elements (SE) used in morphological **OPEN** operations

SE \ size	2	3	4	5
Cross		cr3		cr5
Square	sq2	sq3	sq4	sq5
Round	se2	se3	se4	se5



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Structural Elements (SEs)

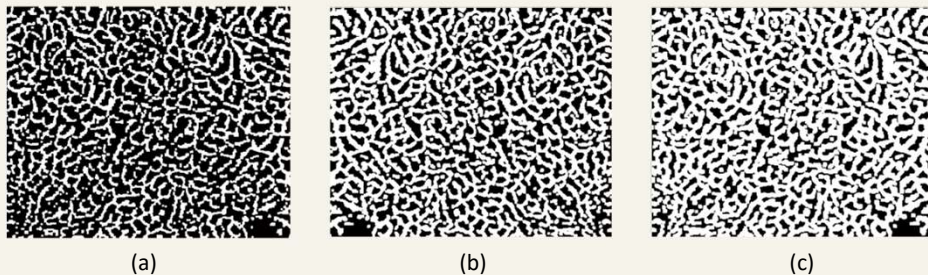
Definition (# indicates SE size)	cr#:	sq#:	se#:
	cr: cross	sq: square	Se: circle
Example	cr5	size=3	size=3



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Feature Extraction



Images obtained after applying morphological OPEN operation: (a)先用sq4侵蝕再用sq4膨脹，(b)先用se2侵蝕再用sq5膨脹，(c)先用se2侵蝕再用se4膨脹。

$$\text{Edge density } d = s/(a - v)$$

a : number of all pixels in ROI

v : pixel number of vessel region

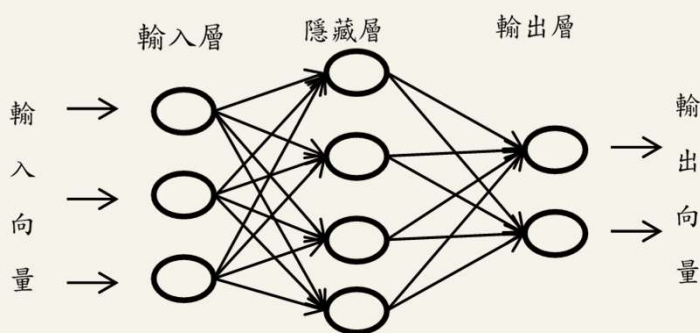
s : edge pixels of the microstructure detected by using Canny operator but not including vessel regions



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Artificial Neural Network



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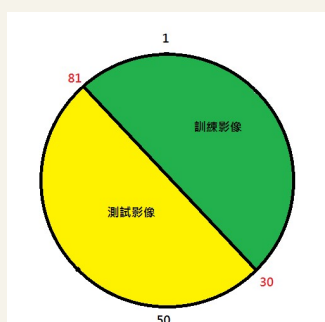
Experiments

- 將數據分為測試(50張異常,5張正常)和訓練(50張異常,5張正常)兩組
- 測試五組不同的類神經網路(五組測試影像和訓練影像不完全相同)
- 依序順時鐘異常旋轉20張,正常旋轉5張

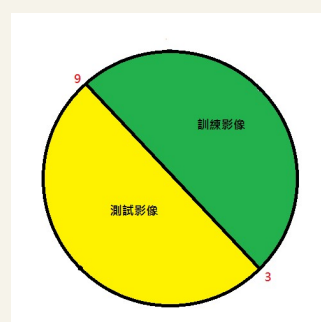


各組分布圖

異常



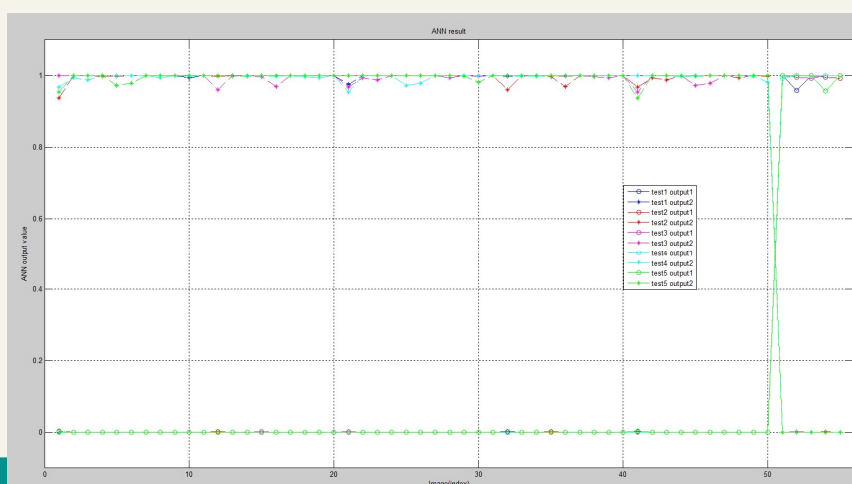
正常



100個參數



Ann result

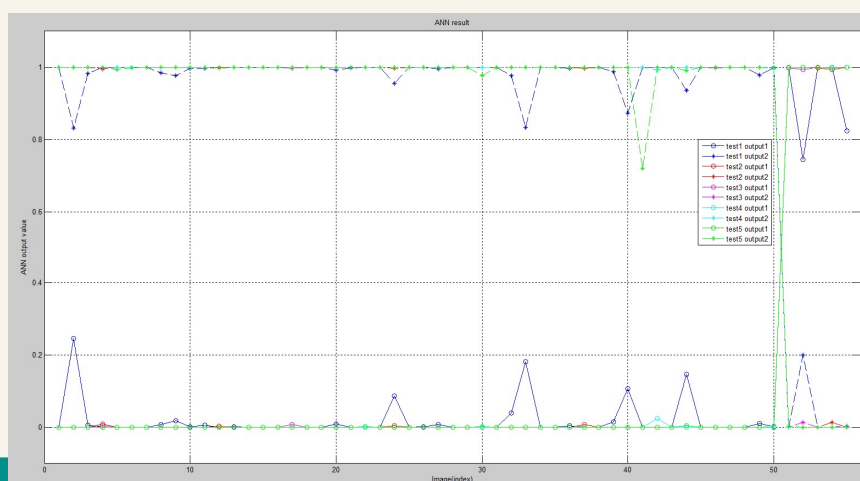


50個參數

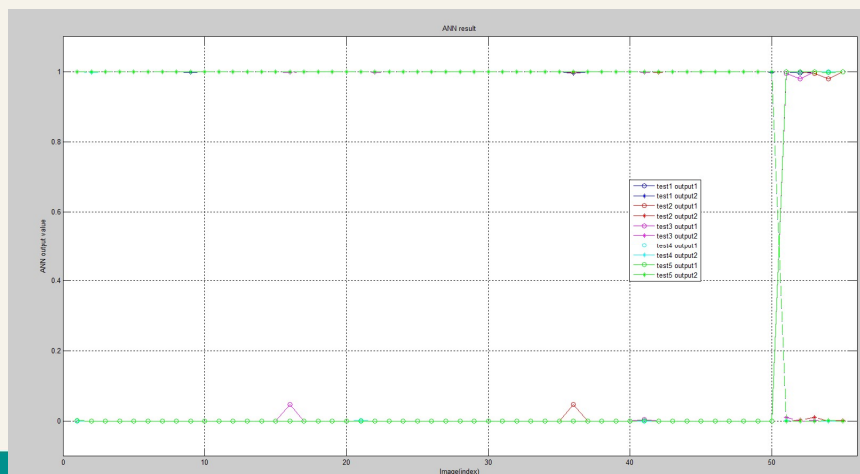
100個參數每2個取一次



Result (第一組)



Result (第二組)



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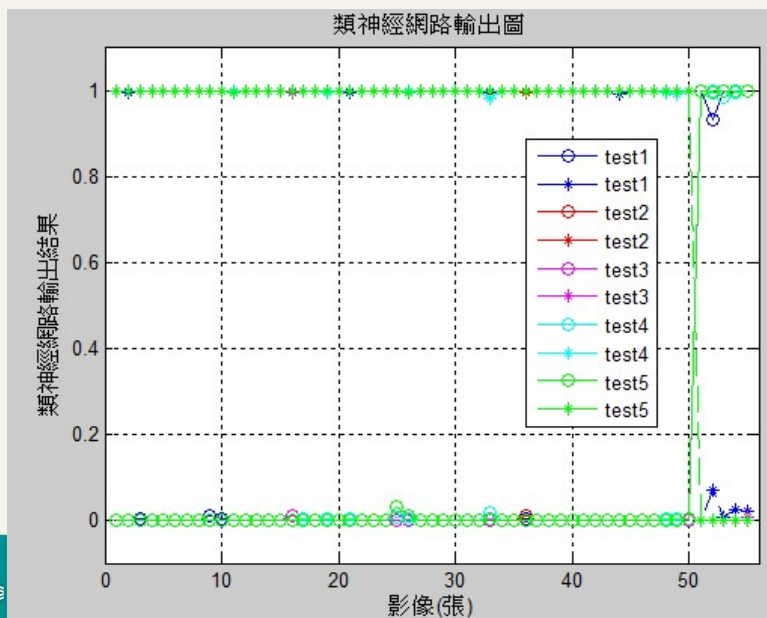
25個參數
100個參數每4個取一次



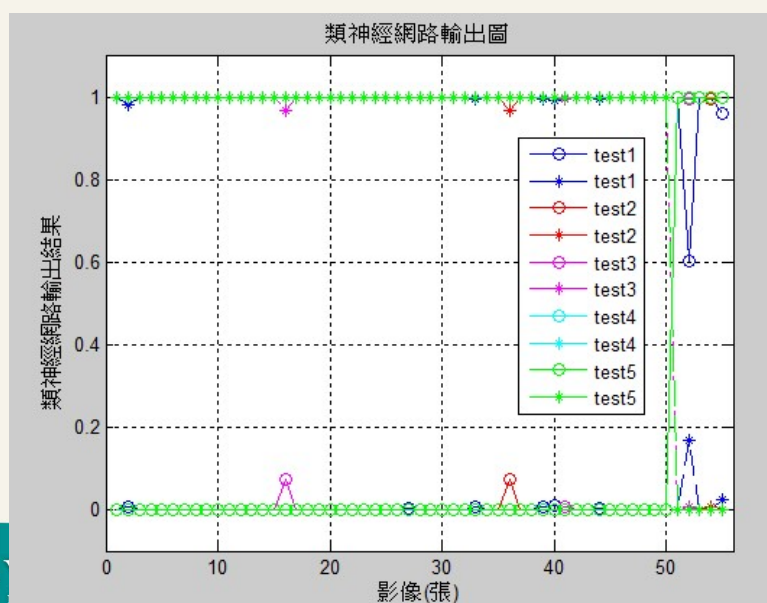
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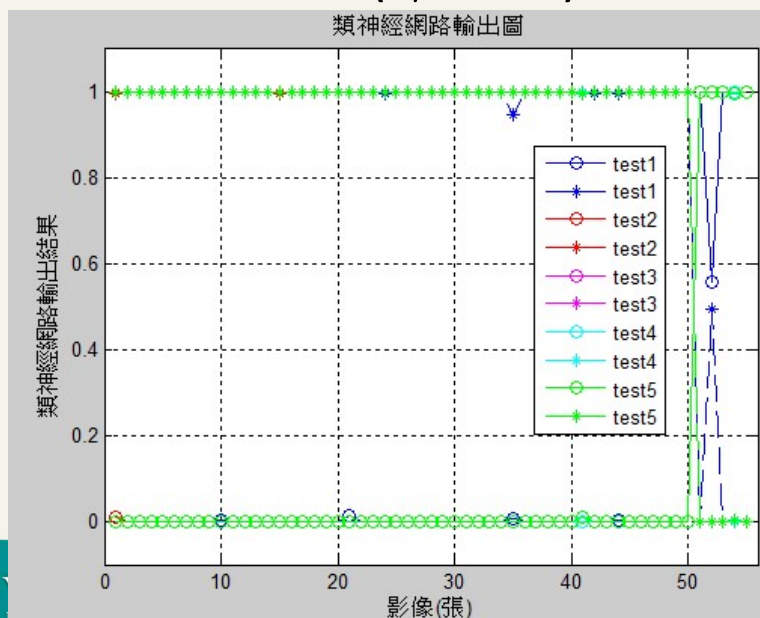
Result (第一組)



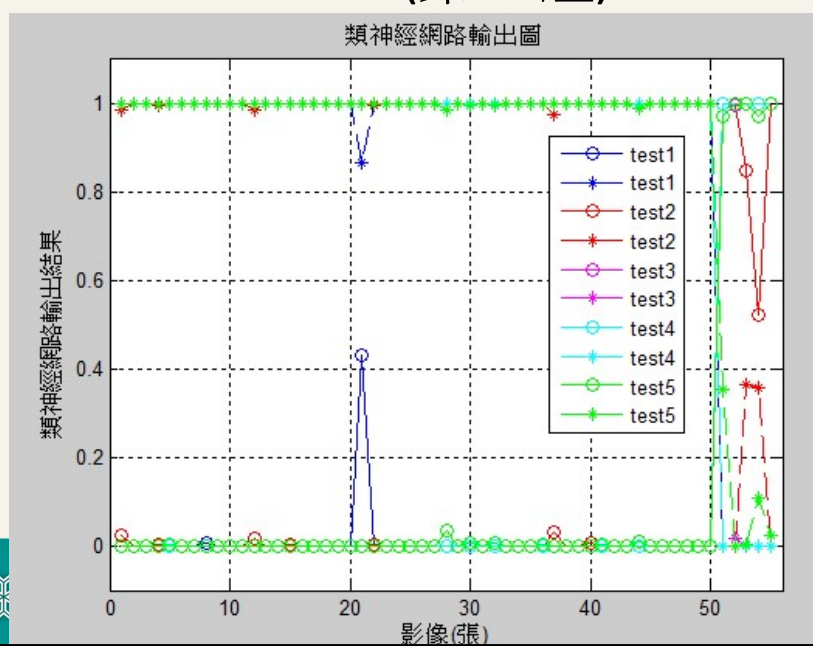
Result (第二組)



Result (第三組)



Result (第四組)

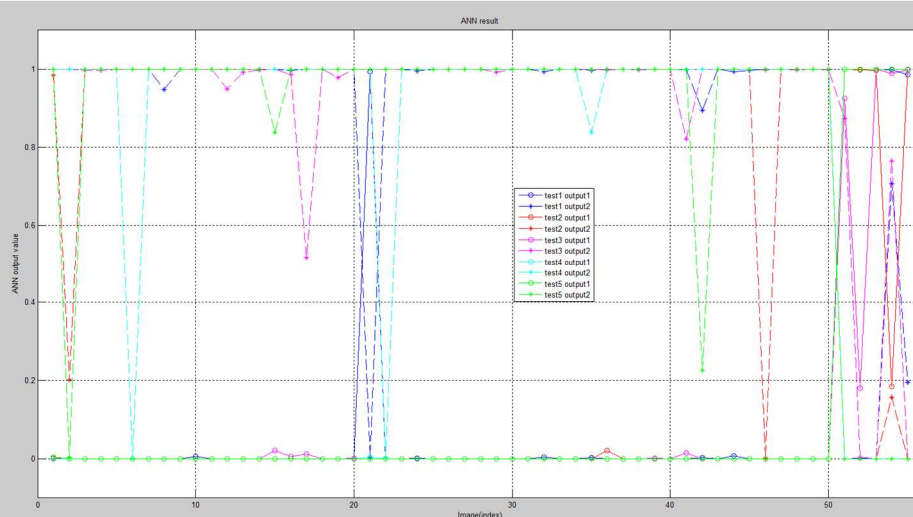


20個參數

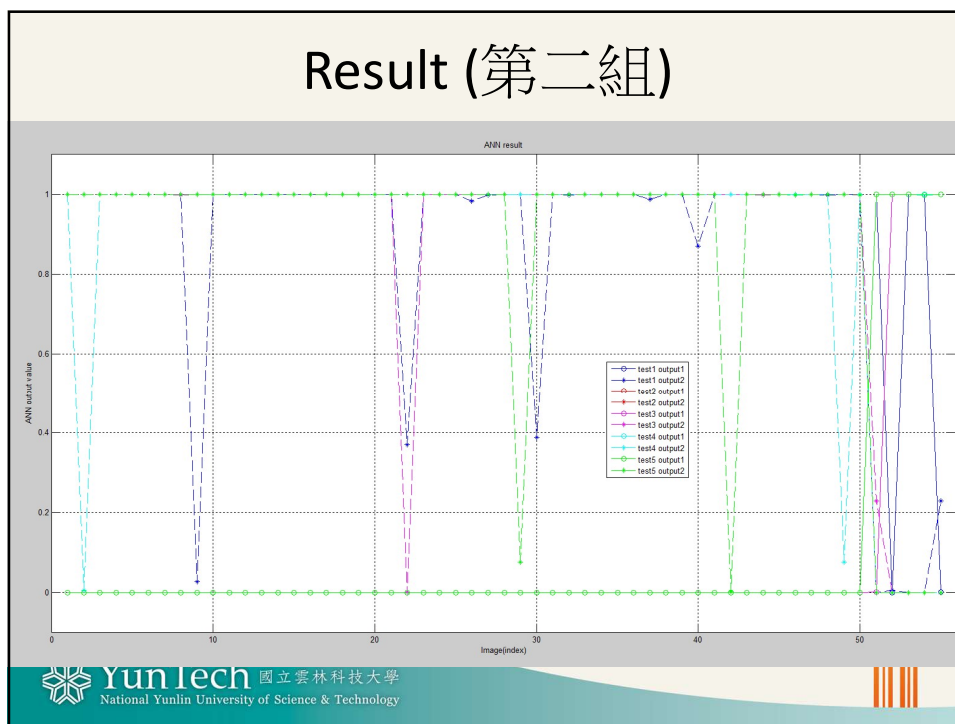
100個參數每5個取一次



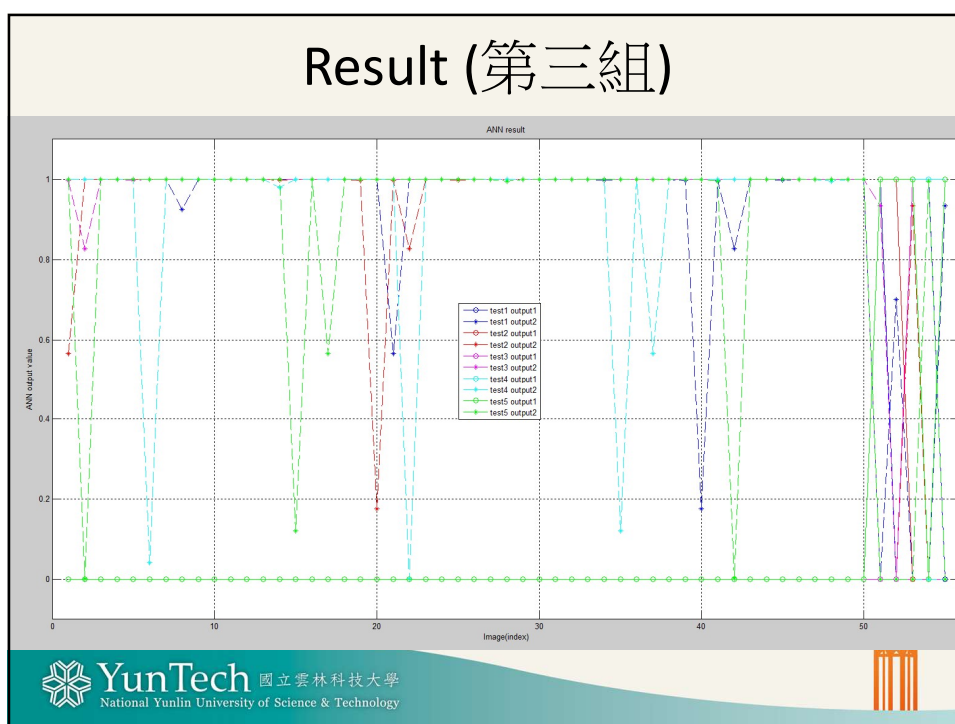
Result (第一組)



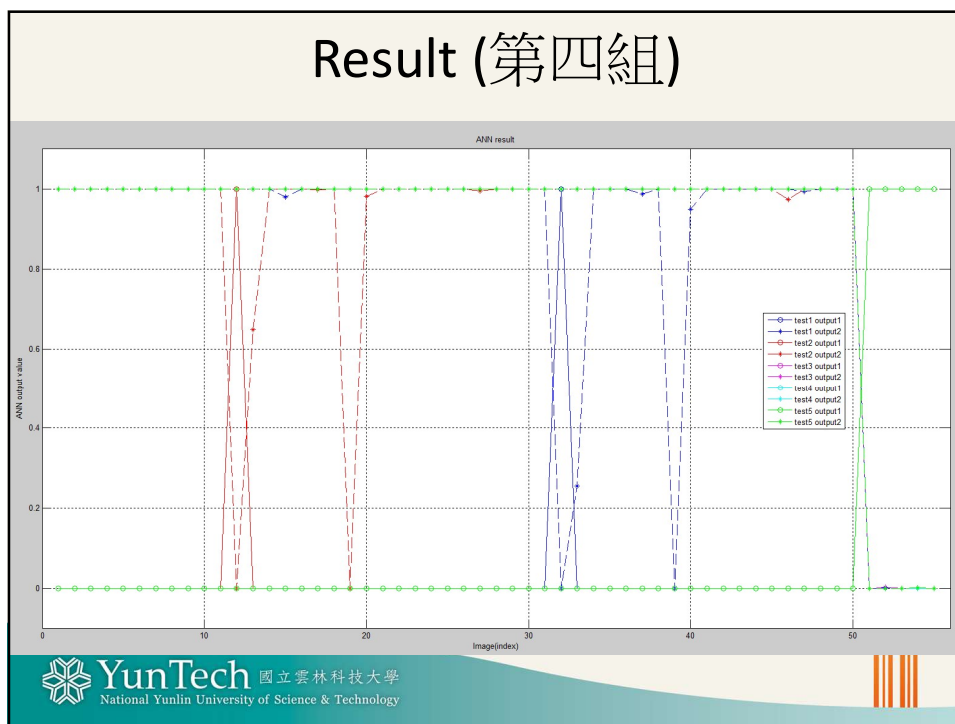
Result (第二組)



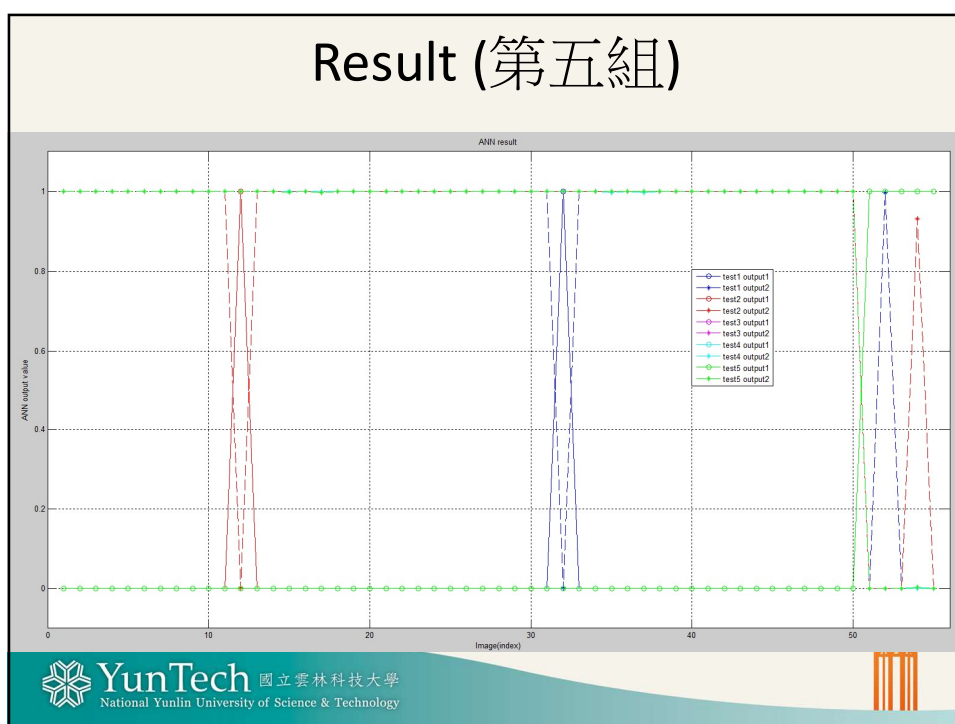
Result (第三組)



Result (第四組)



Result (第五組)



Accuracy and computation time

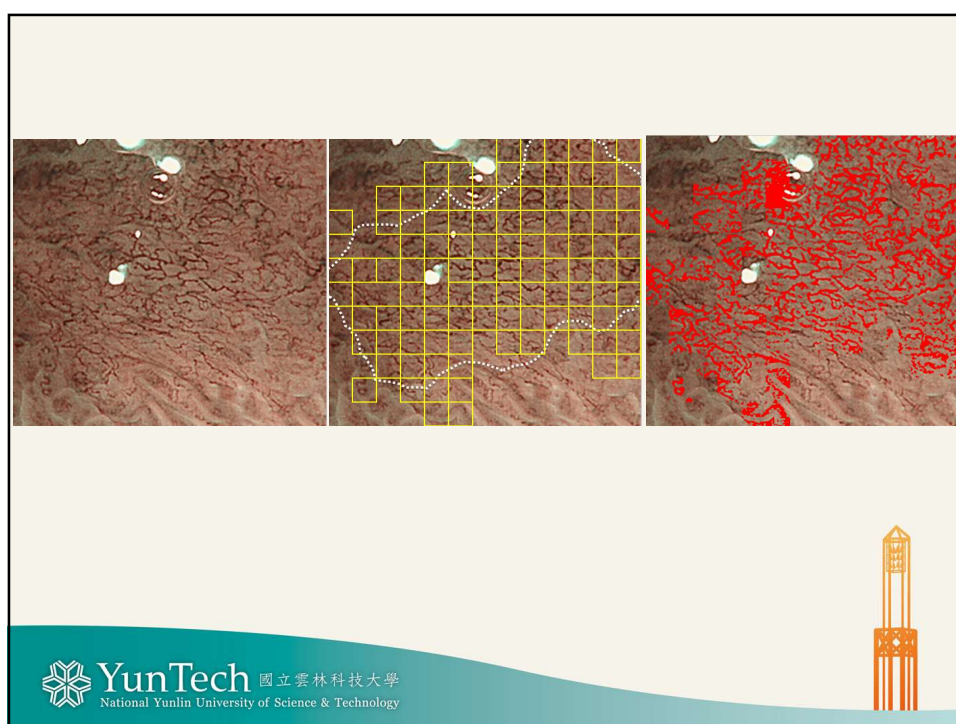
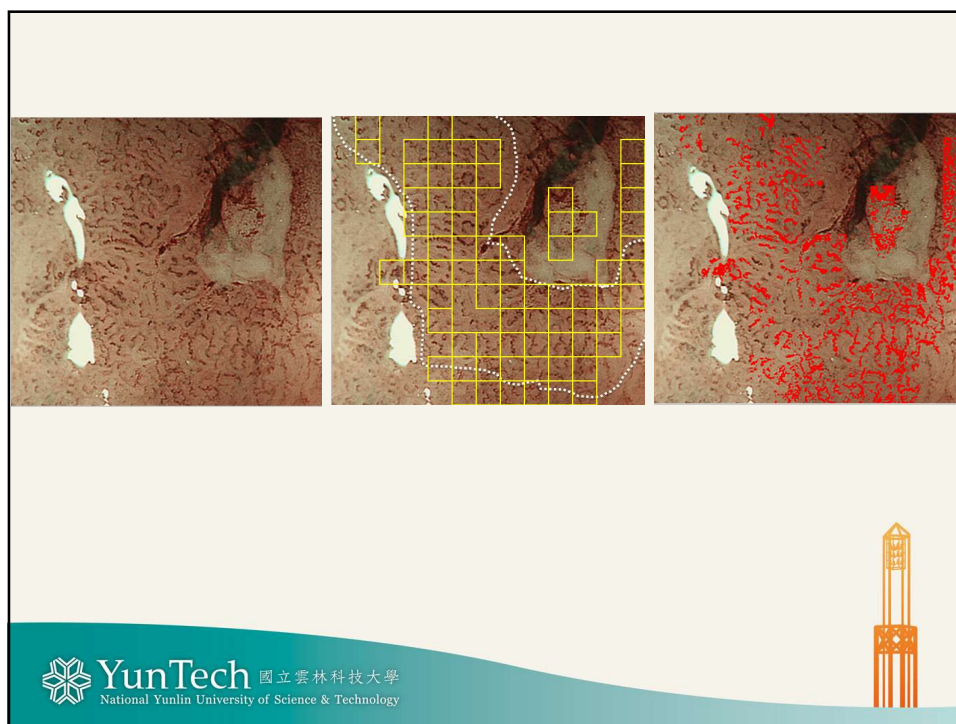
ACCURACY	Test1	Test2	Test3	Test4	Test5	Ttime (s)
20個參數	94.5%	96.7%	97.4%	97.4%	97%	2.1
25個參數	100%	100%	100%	100%	100%	2.5
50個參數	100%	100%	100%	100%	100%	4.75
100個參數	100%	100%	100%	100%	100%	8.62

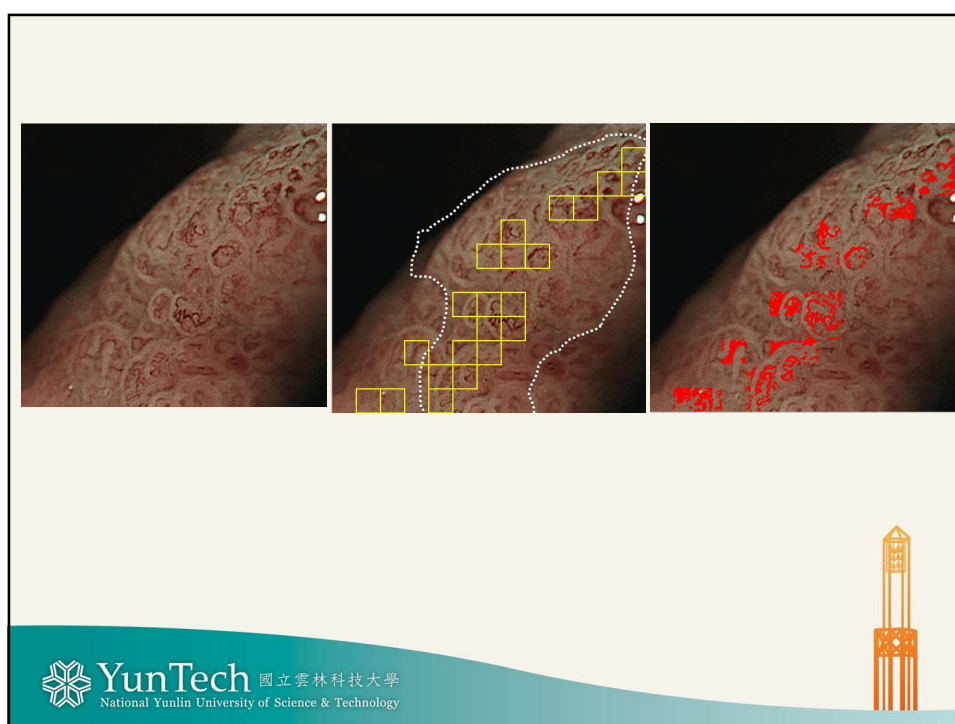
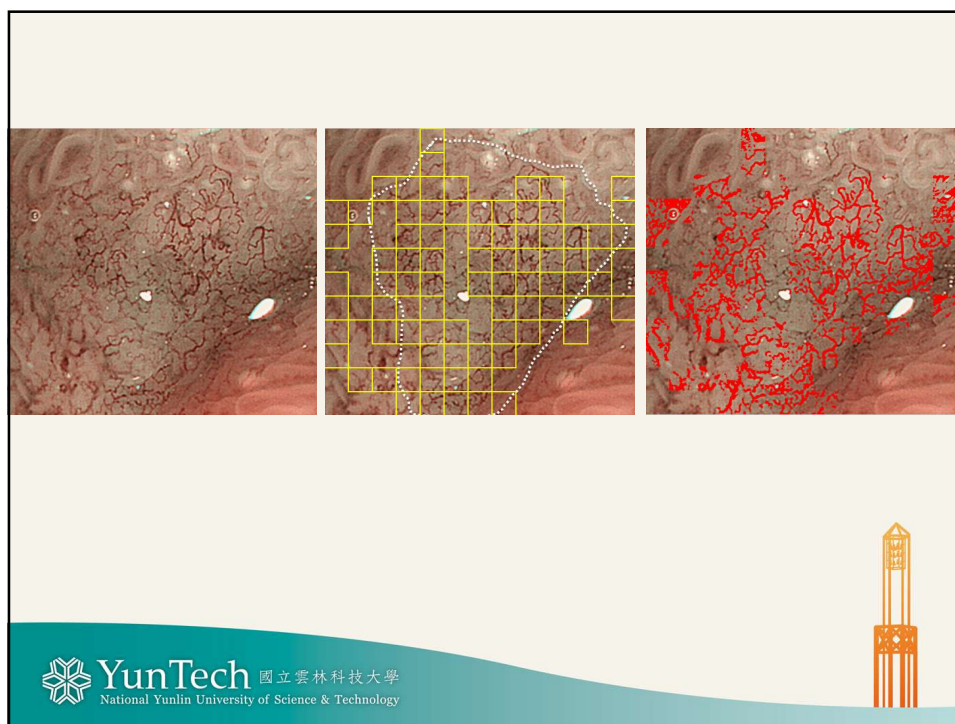


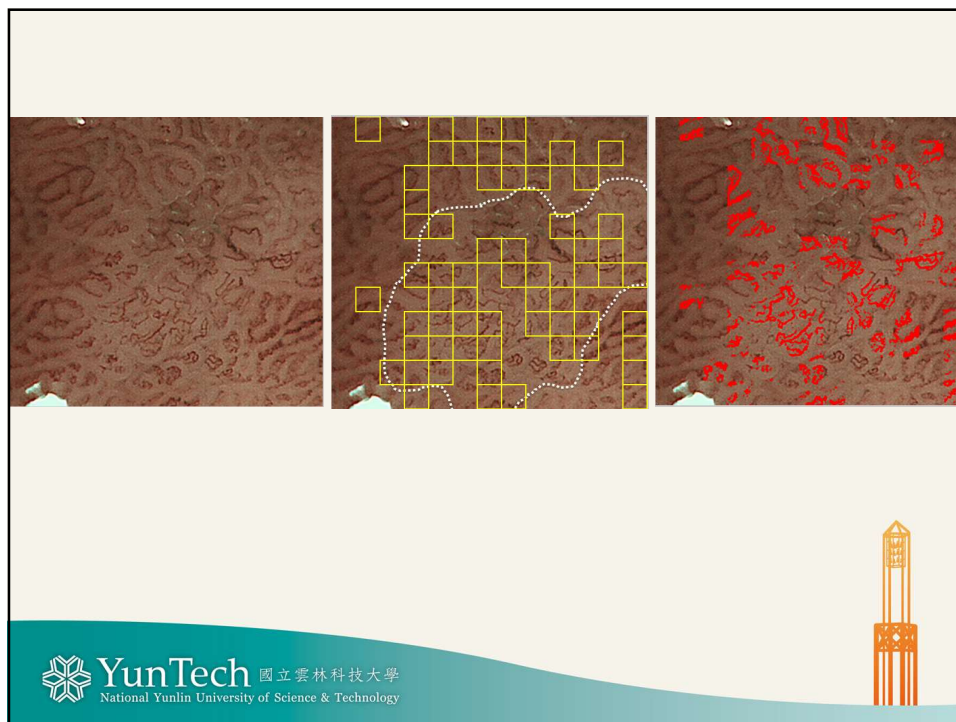
Identify the micro-vessels in the image is more meaningful

1. Determine normal or abnormal image
2. If abnormal, enter block-based detection
3. Identify abnormal image blocks
4. Micro-vessel segmentation for each block
5. Label the vessels corresponding to gastric cancer



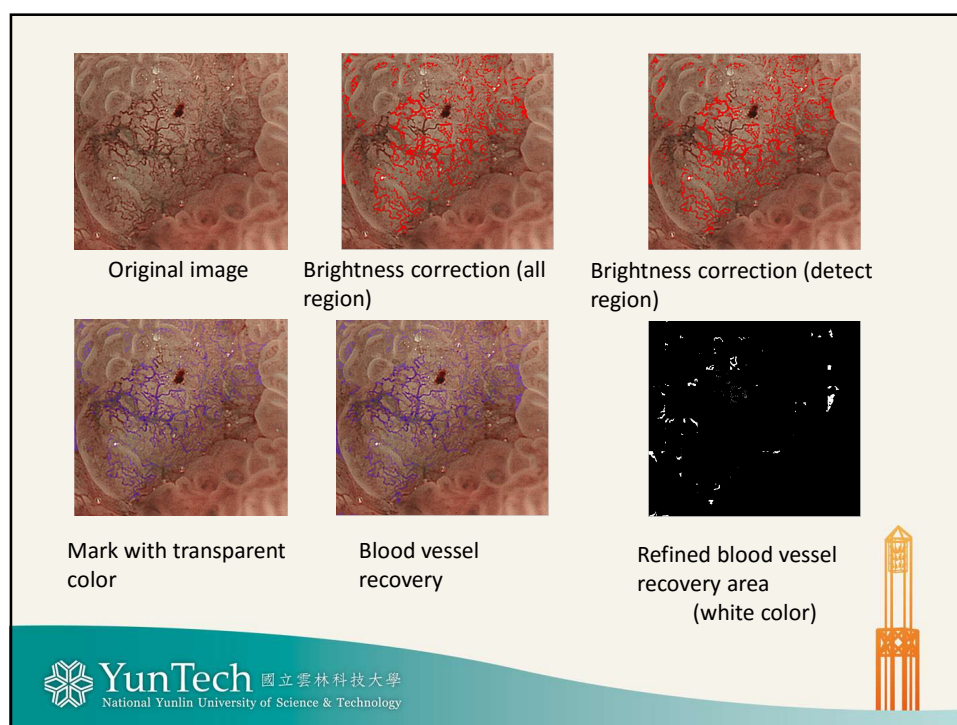


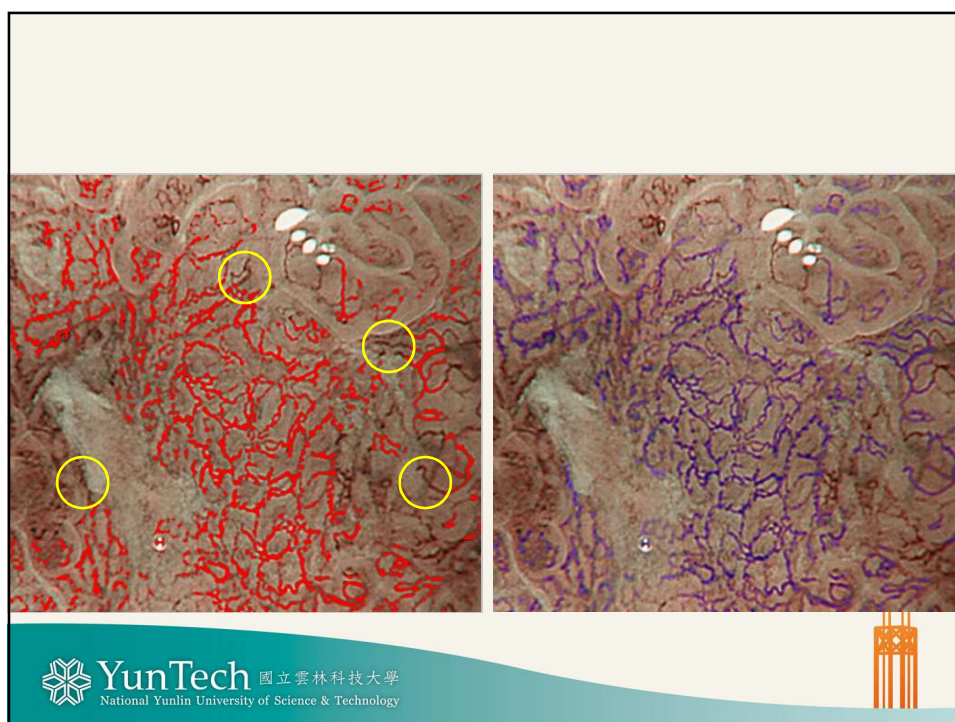
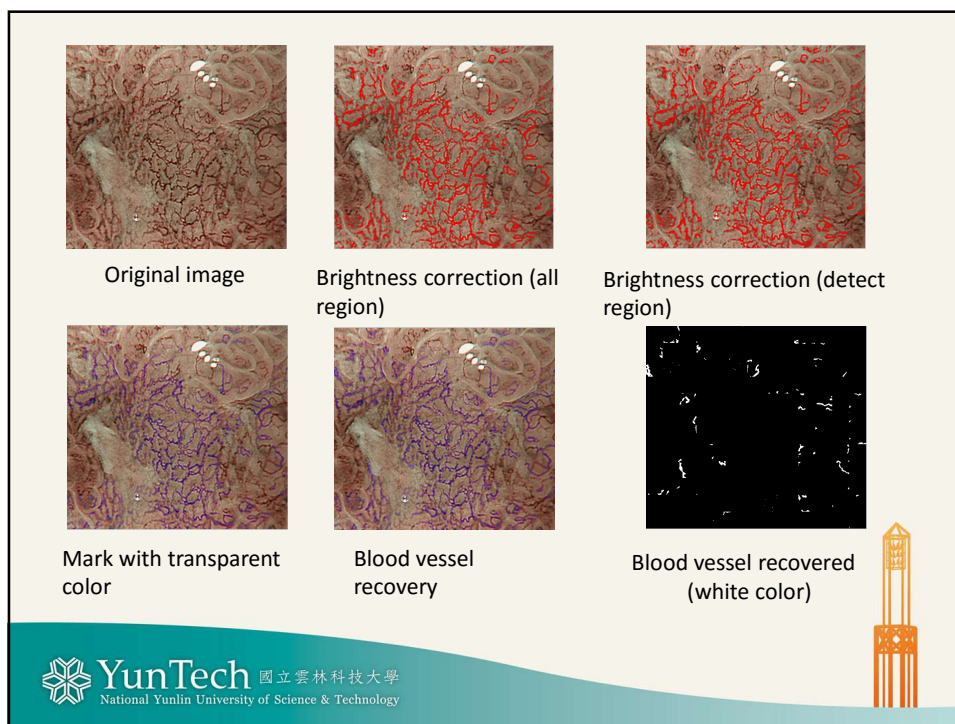


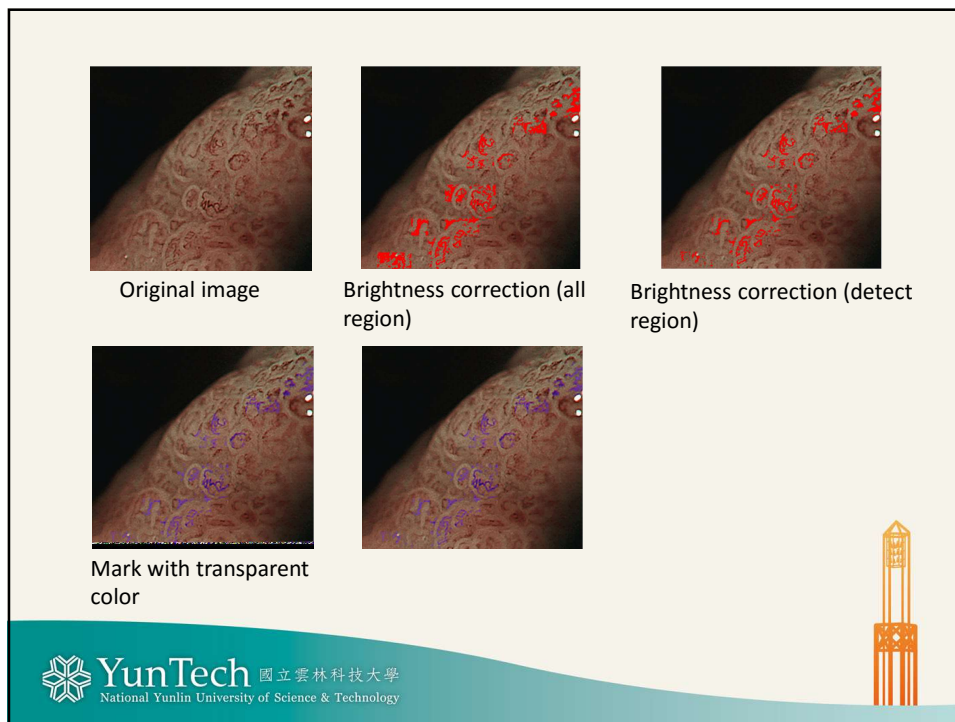


Refinement on Vessel Representation

- Blood vessel marked with transparent color
- Brightness correction
 - all region (whole image) $\rightarrow$ if darkness area pixel < 10000
 - detect region only $\rightarrow$ if darkness area pixel number > 10000
- Vessel recovery







Summary

- NBI endoscopy image analysis
 - Analyze gastroendoscopy images for early stage gastric cancer detection
- Transform doctors' diagnosis rules/experiences into computer algorithms
 - Provide auxiliary diagnosis tools during examinations
 - Suitable for training purpose

Ongoing Work

- Better extraction on microvascular network & microsurface structure
 - Robust to nonuniform illumination and large content diversity
- Define **metrics** for measuring caliber width & variation, shape & curvature, etc.
- Automatic detection on suspicious features in magnified NBI images



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Thank you for your attention!

