Image Processing in Unconventional Applications

Simying Ong (*Ph.D.*)
FCSIT UM
6th October 2020

simying.ong@um.edu.my
ongsimying@gmail.com

simying.ong@um.edu.my
ongsimying@gmail.com

Digital Image vs Visual

Goto menti.com and enter 19 55 10 5

Digital Image vs Visual

- Human *Visual* Perception
- What we can see
- + Brain → “Mysterious” perceptual and cognitive processing centre
- **More than digital image**

- “Saving format”?
  - Text
  - Light, depth data
  - Movement data
  - Continuous images
  - Signal

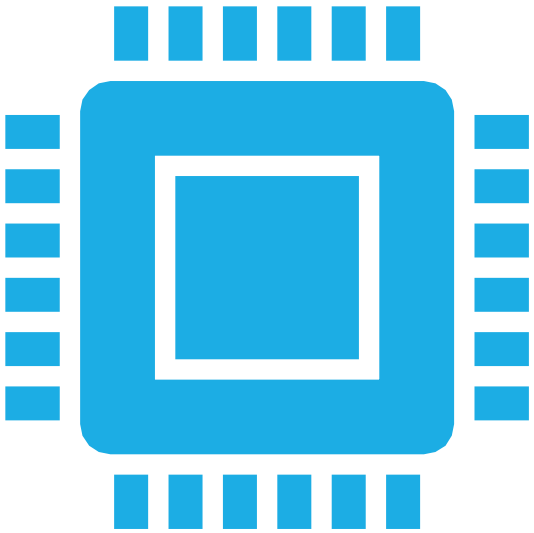
- Has limit, scope, boundary
- 2D or 2.5D
- **Picture** produced on an electronic display (from *visual* source)

- Saved into image standard format:
  - JPG. JPEG
  - PNG
  - TIFF
  - BMP
  - WebP

simying.ong@um.edu.my
ongsimying@gmail.com

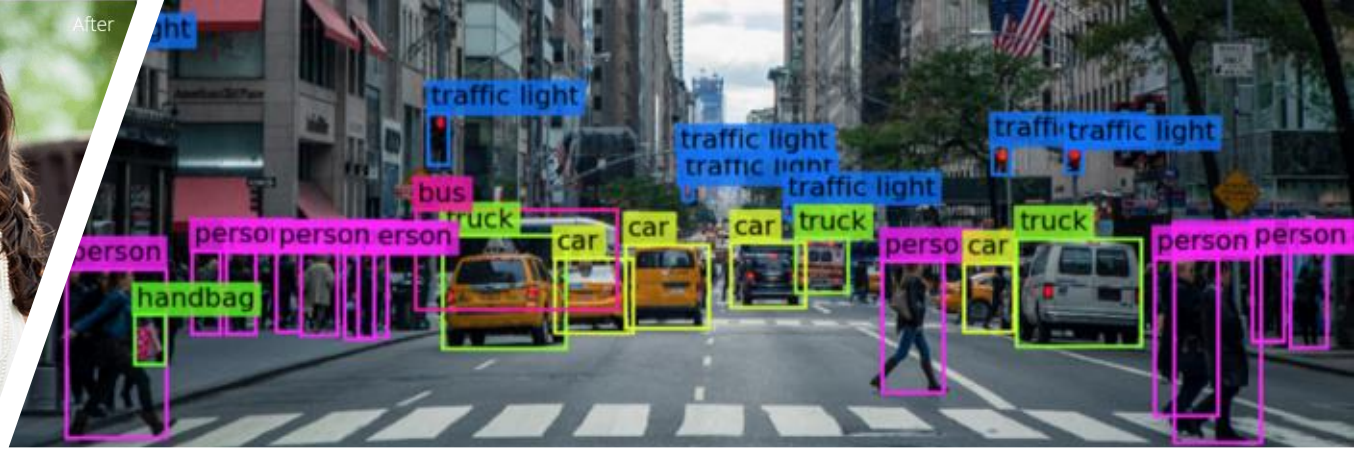
There are overlapped information.
BUT we focus on Digital Image in this presentation.

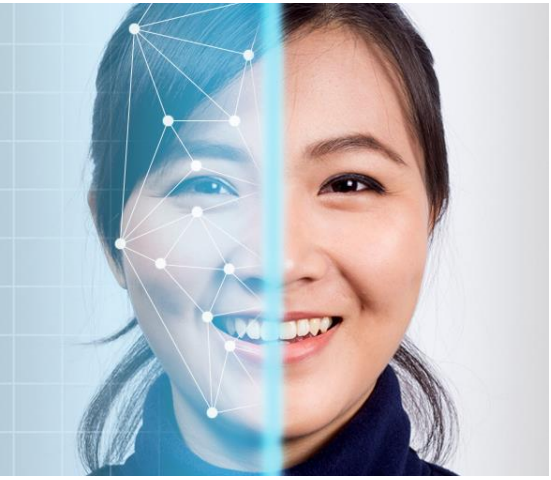
simying.ong@um.edu.my
ongsimying@gmail.com



Digital Image Processing and its Applications

What are the applications that you have learned so far in this subject?





Digital Image Processing and its Applications

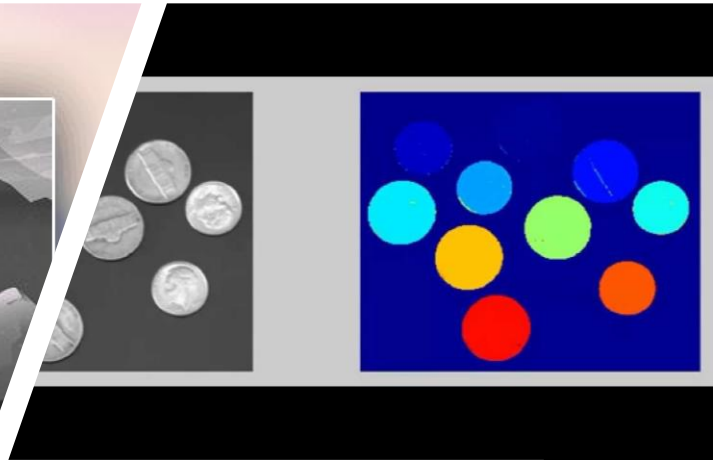
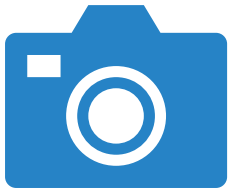


Image Processing vs Image Analytic



simying.ong@um.edu.my
ongsimying@gmail.com

Image processing

Colour processing
Contrast enhancement
Resize
Crop

image analytic

Beyond image processing
Extract meaningful information
Do interpretation
Segmentation, detection, etc.

Inseparable

simying.ong@um.edu.my
ongsimying@gmail.com

Image Processing and its Unconventional Applications

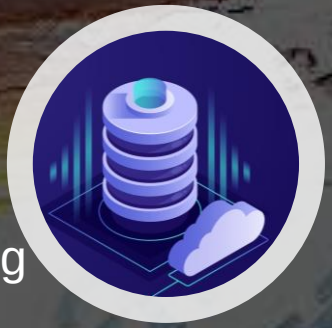
- Mixture of Image Processing and Image Analytic techniques:

1. **Information hiding**
2. Image recovery using linear optimization
3. On-orbit image enhancement and characterization
4. Others…

simying.ong@um.edu.my
ongsimying@gmail.com

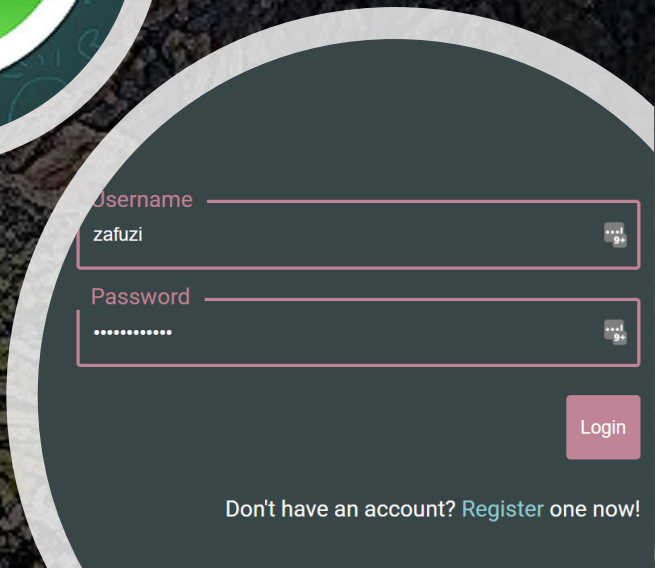
Unconventional Application
Information Hiding

What is IH?



- The art and science of concealing information.
- Exist in our day-to-day applications:
  - ❑ Login system (protected password ******)
  - ❑ File system (metadata)
  - ❑ Whatsapp (Encrypted conversation)
  - ❑ Database (Hashed data)
  - ❑ Artwork (watermark)
  - ❑ Others….

simying.ong@um.edu.my
ongsimying@gmail.com



Two disciplines in IH

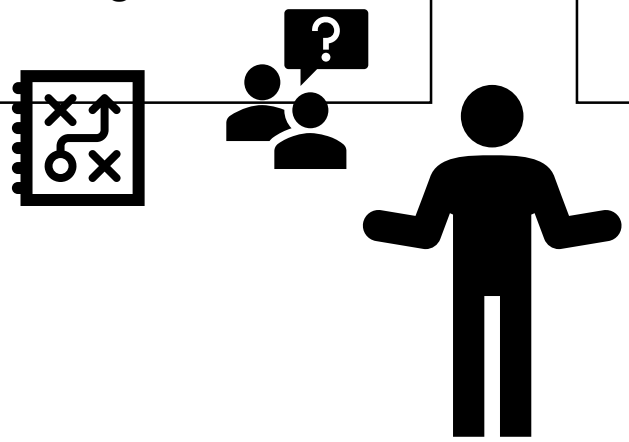
Encryption

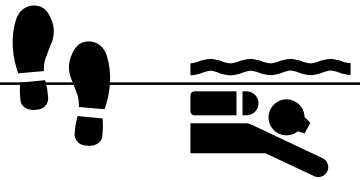
Conceal the perceptual meaning of the media files to make it unreadable or unintelligible.

Data Insertion

Embed internal / external data into the media files while maintaining the perceptual display.

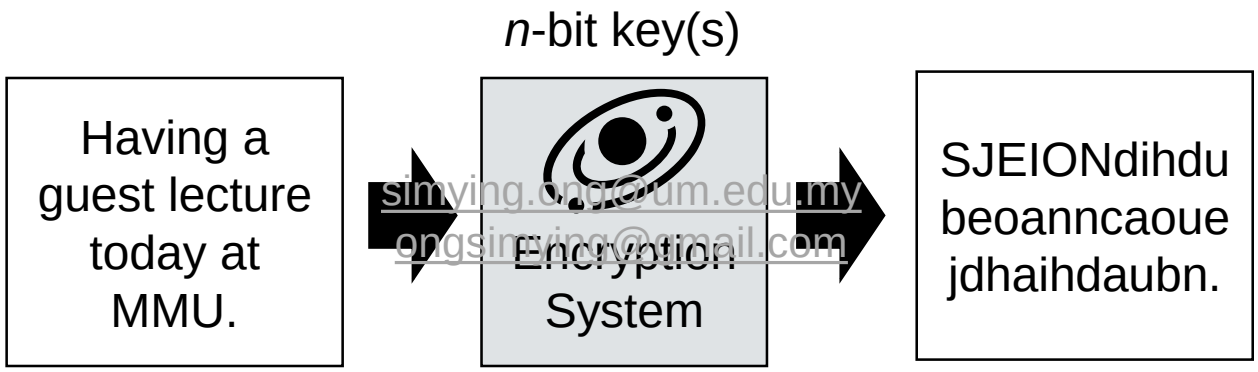
simying.ong@um.edu.my
ongsimying@gmail.com





Encryption

- Standard Encryption Methods:
  - AES (Advanced Encryption Standard), DES (Data Encryption Standard), Hash, etc.



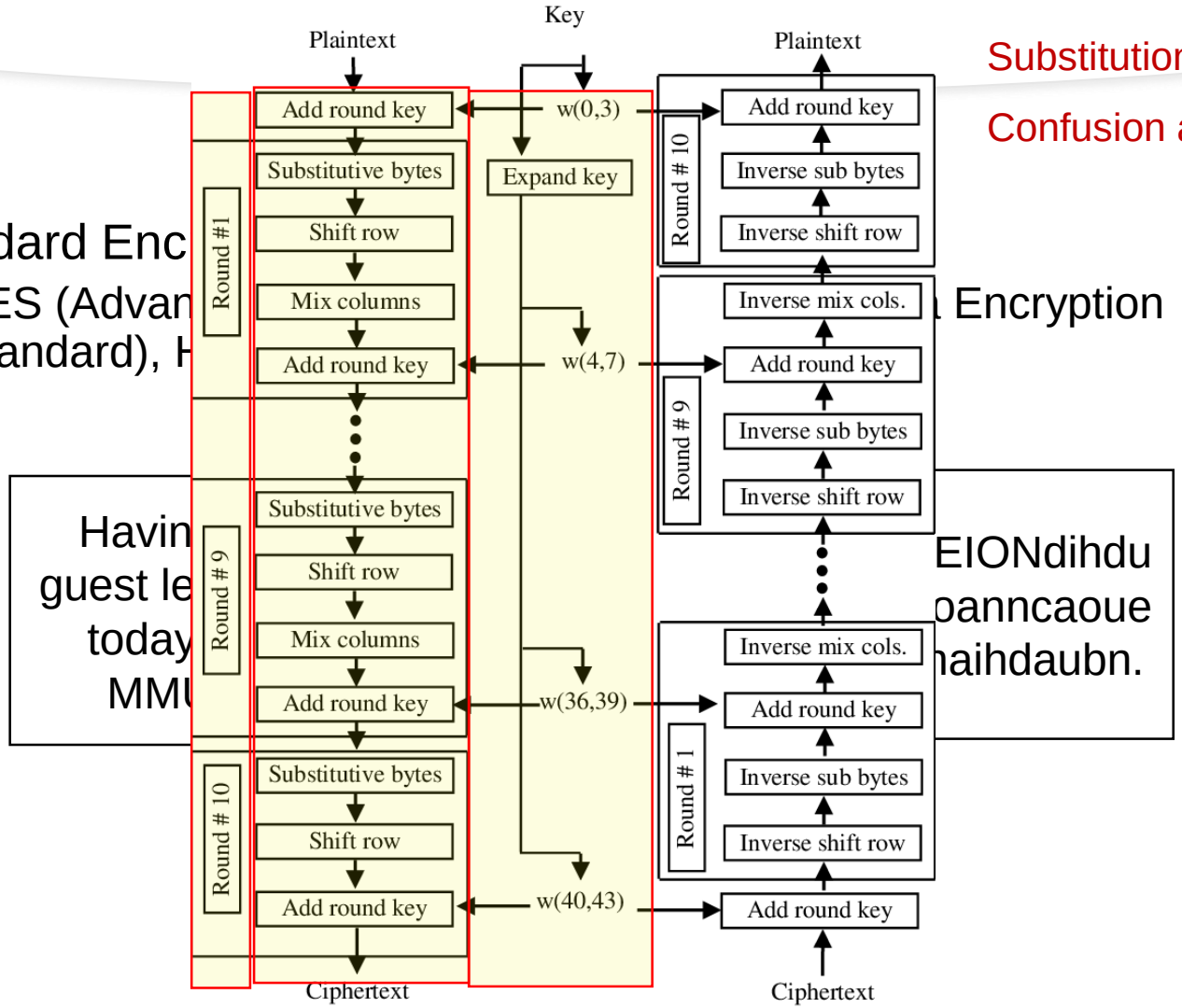
simying.ong@um.edu.my
ongsimying@gmail.com

Encryption

Substitution and permutation

Confusion and diffusion

- Standard Enc
  - AES (Advan Encryption Standard), H



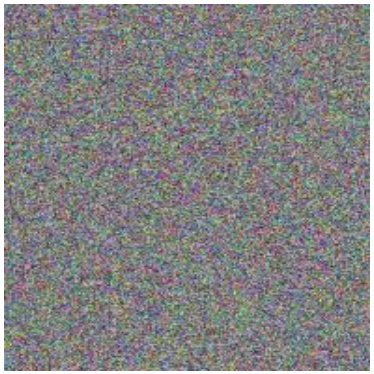
Havin
guest le
today
MMU

EIONdihdu
oanncaoue
naihdaubn.

Image Encryption

- Conceal the perceptual meaning of the **image** to make it unreadable or unintelligible.

n-bit key(s)



Chaotic theory
Transform approach
DNA Coding
S-boxes

22,500 papers in 2020!

simying.ong@um.edu.my
ongsimying@gmail.com

Data Insertion

440BC – Ancient Greece – Head of the slave (steganography)

Steganos (covered / secret) and *–graphy* (writing)

Data Insertion in Text

Information Hiding – Protecting your Digital Files in a Modern Way

Simying Ong (simying.ong@um.edu.my)
Faculty of Computer Science and Information Technology

Let's us start by asking ourselves the following question:

- Do you share your picture or document online?

If the answer is positive, ask yourself the next question: Did you *protect* these digital files?

Most of us will share the same answer - *no*. We often assume that *we will be fine if we set the privacy setting to private*. But, does this assumption hold true all the time ? Realistically saying, once you shared your phone online, it will be existed online *almost forever*, even after you deleted it later.

If we do not protect our digital files (e.g., document, pictures, email, etc.) when we are sharing, transmitting and storing it online, the consequences can be disastrous. Infringer might take or steal your digital files and misuse them to ultimately gain financial benefits via identify theft, copyright infringement, etc.

Information Hiding is one of the prominent solutions when it comes to digital files protection. It is divided into two major disciplines including encryption and data insertion. Encryption conceals the perceptual view of the digital files by making it unintelligible while data insertion embeds additional information (e.g., watermark, metadata) into it. In recent years, techniques from both disciplines and its reverse process were often integrated to complement each other in creating a well-rounded protection scheme. Apart from inserting identification / authentication data in protecting the copyright of the digital files, encryption is added to transform it in ensuring secure transmission / storage via the Internet or cloud.

Data Insertion in Text

Information Hiding – Protecting your Digital Files in a Modern Way

Simying Ong (simying.ong@um.edu.my)
Faculty of Computer Science and Information Technology

Let's us start by asking ourselves the following question:

- Do you share your picture or document online?

If the answer is positive, ask yourself the next question: Did you *protect* thes

Most of us will share the same answer - *no*. We often assume that *we* *set the privacy setting to private*. But, does this assumption hold true Realistically saying, once you shared your phone online, it will be existed online *al* *forever*, even after you deleted it later.

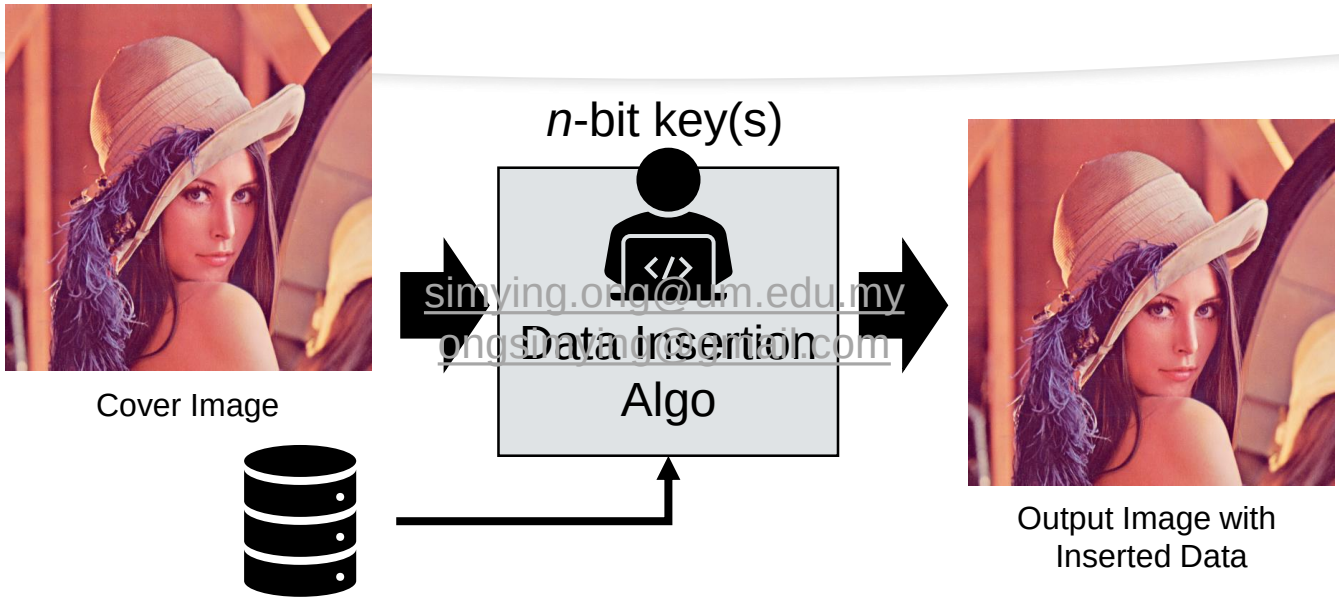
If we do not protect our digital files (e.g., document, pictures, email, etc.) when we are s transmitting and storing it online, the consequences can be disastrous. Infringer might tak or steal your digital files and misuse them to ultimately gain financial benefits copyright infringement, etc.

Information Hiding is one of the prominent solutions when it comes to digita is divided into two major disciplines including encryption and data ins conceals the perceptual view of the digital files by making it unintelligible w embeds additional information (e.g., watermark, metadata) into it. In recent from both disciplines and its reverse process were often integrated to comp in creating a well-rounded protection scheme. Apart from insertin authentication data in protecting the copyright of the digital files, encry transform it in ensuring secure transmission / storage via the Internet or cloud.

Space, font characters, synonym, dictionary, mask, etc.

Ultimate goal – make sure that it does not create suspicion.

Modern Day Data Insertion



- Many types of data insertion applications in images:
  - **Steganography**: conceal message communications
  - **Watermark**: protect copyrighted materials
  - **Fingerprint**: trace illegal distributors upon legal dispute
  - **Metadata insertion**: organization or searchable purposes (radio advert.)
  - Many others…

Unified IH (UIH)

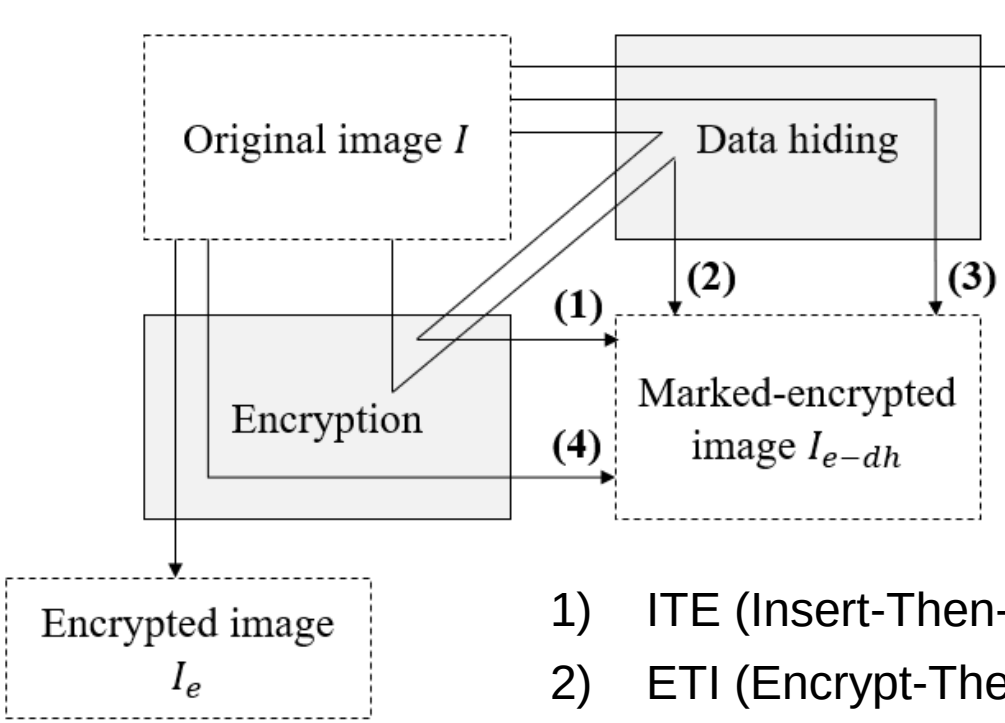
Encryption + **Data Insertion**

- Combining both disciplines in a single framework. ***Why?***

Digital Right Management (digital image provider)	**Cloud Storage and Management**	**Surveillance Video Recording**	**Classified information management**
Insert fingerprint into image and encrypt it for secure transmission.	Encrypt for secure storage and metadata insertion for search management.	ROI encryption for user privacy and metadata for legal purposes.	Multi level encryption for different level access and metadata for content management.

simying.ong@um.edu.my
ongsimying@gmail.com

Unified IH (UIH)



1) ITE (Insert-Then-Encrypt)
2) ETI (Encrypt-Then-Insert)

Intuitive ways to achieve unification

3) I2E (Insert-To-Encrypt)
4) E2I (Encrypt-To-Insert)

Can we do it in single step?

Reference:
S. Ong, Ph.D. Thesis, 2015 [http://studentsrepo.um.edu.my/5519/2/WHA100032_ONG_SIM_YING_PhD_Thesis.pdf]

simying.ong@um.edu.my
ongsimying@gmail.com

Sub-Outline

- Unified IH in spatial domain (General)
- Unified IH in compressed signal domain (General)
- Coverless IH
- Photo Effects Embedding

Spatial Domain vs Frequency Domain

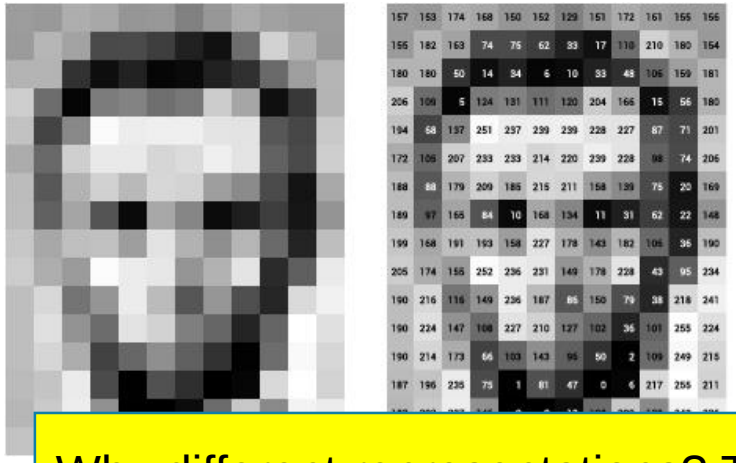
Spatial Domain

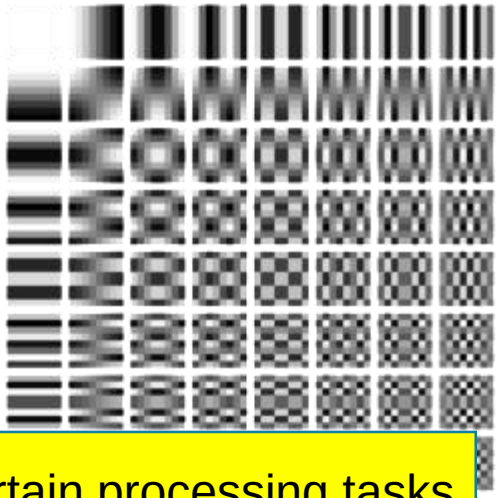
- Work on the **pixel values** of the image
- Integer.

simying.ong@um.edu.my
ongsimying@gmail.com

Frequency Domain

- Work on the **signals** represented by math functions.
- Has coefficients and variables.





Why different representations? To ease certain processing tasks and find new information in different domains.

simying.ong@um.edu.my
ongsimying@gmail.com

Unified IH in Spatial Domain

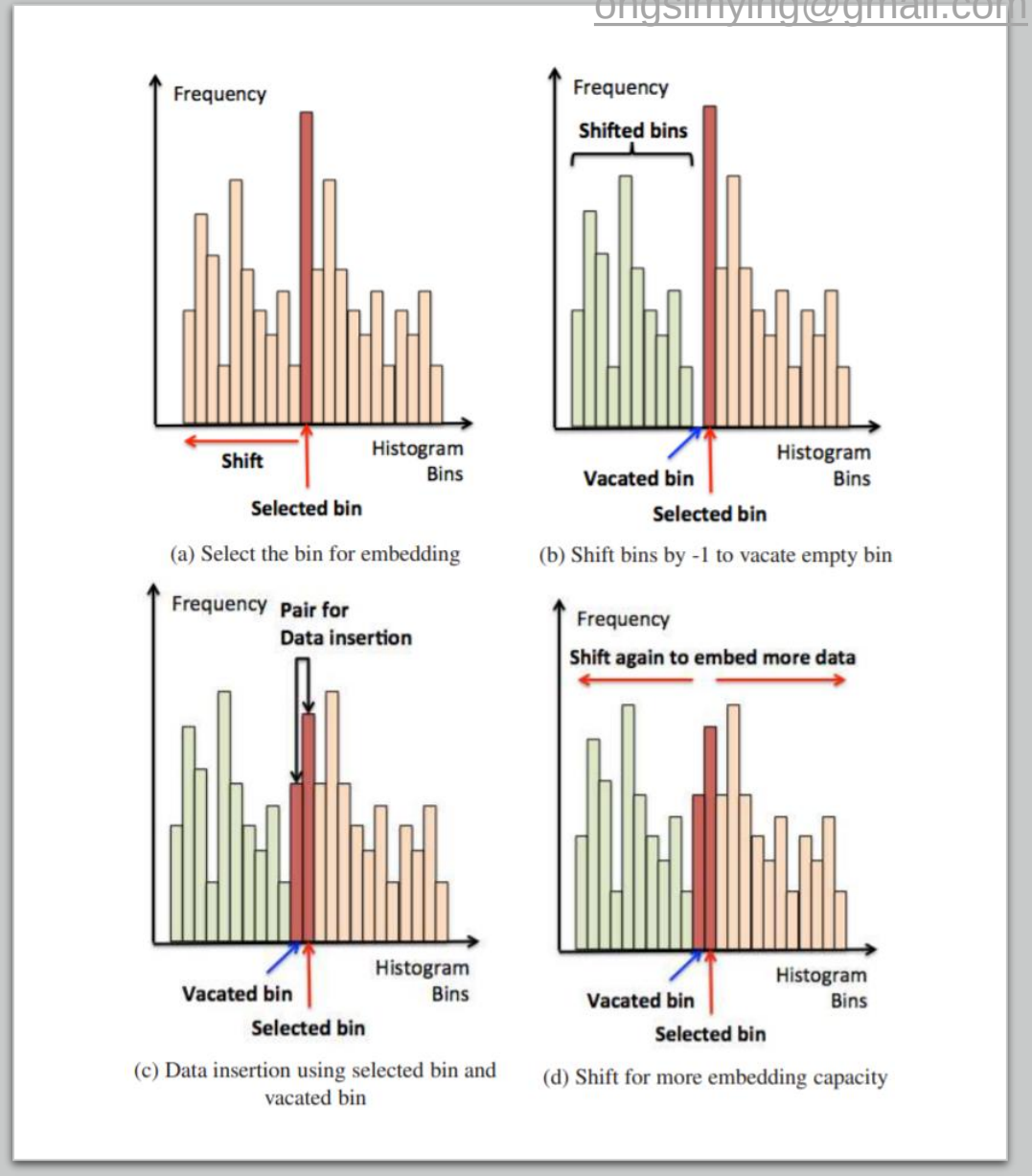
References:

- **S. Ong,** K. Wong, and K. Tanaka, A Scalable Reversible Data Embedding Method with Progressive Quality Degradation Functionality", Signal Processing: Image Communication, 29 (1), pp. 135-149, Jan. 2014.
- **S. Ong,** K. Wong and K. Tanaka, "Improvement on Reversible Data Embedding Method using Virtual Queue Decomposition", IIEEJ 3rd Image Electronics and Image Computing Workshop (IEVC), 21-24 Nov. 2012.
- **S. Ong,** K. Wong and K. Tanaka, "Reversible Data Embedding using Reflective Blocks with Scalable Visual Quality Degradation", 2012 IEEE International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP),18-20 July 2012.

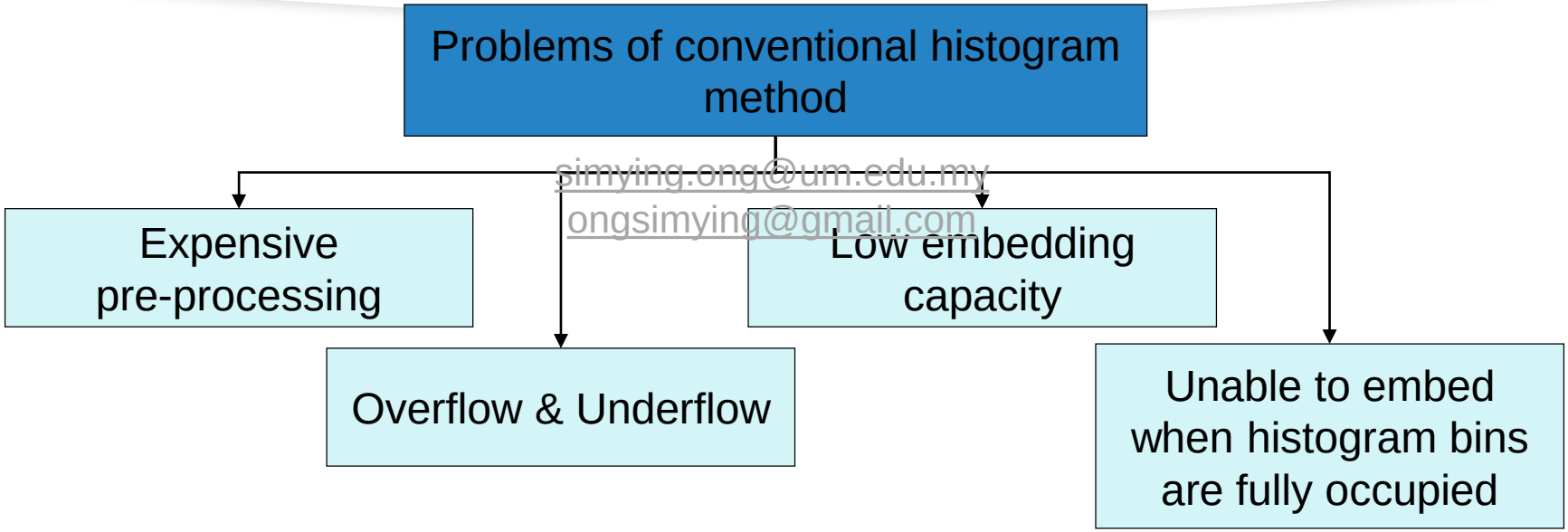
simying.ong@um.edu.my
ongsimying@gmail.com

Spatial Domain - Histogram-based method

- Histogram Shifting (Ni et al., 2006)
- And many others after that…
- UIH – combine with other methods



Histogram-based Method
Problems

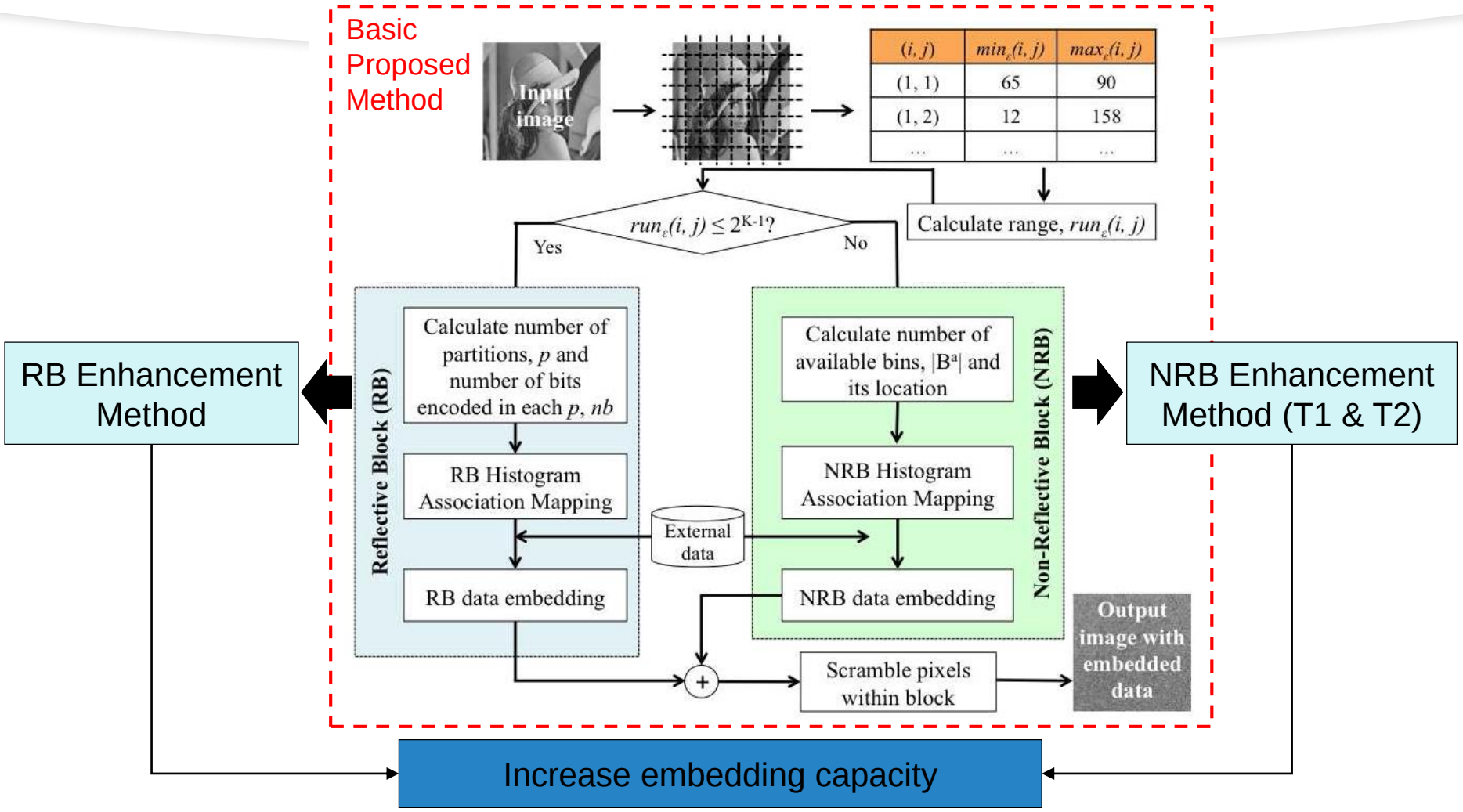


simying.ong@um.edu.my
ongsimying@gmail.com

What if we embed to the **maximum embedding capacity**?
Proposed Histogram Association Mapping (HAM) using I2E approach.

simying.ong@um.edu.my
ongsimying@gmail.com

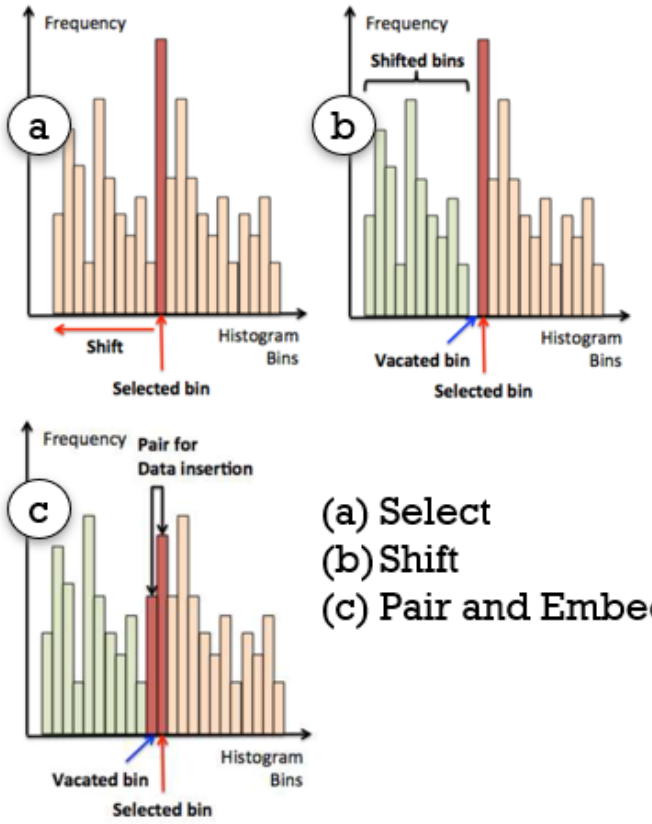
Proposed HAM



simying.ong@um.edu.my
ongsimying@gmail.com

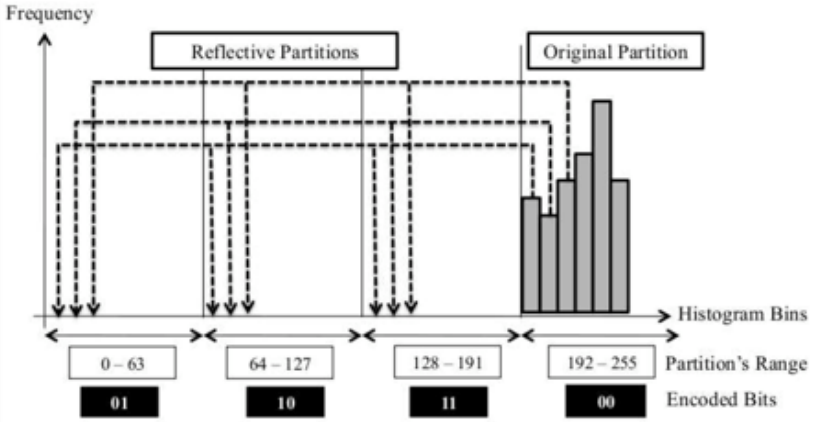
Proposed HAM

Conventional Method



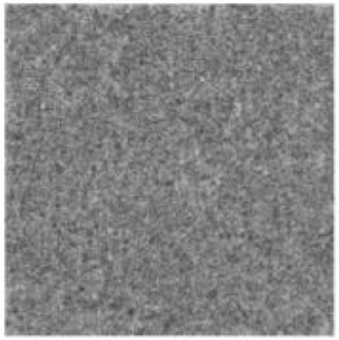
(a) Select
(b) Shift
(c) Pair and Embed

Proposed HAM



- No shifting required
- Block-based technique
- 1 to many mapping

Outcome?



Problems of conventional histogram method

- Expensive pre-processing
- Overflow & Underflow
- Low embedding capacity
- Unable to embed when histogram bins are fully occupied

simying.ong@um.edu.my
ongsimying@gmail.com

Histogram Association Mapping – use parameter to flexibly scale from Hide Data + No Encryption → Max Data + Full Encryption

simying.ong@um.edu.my
ongsimying@gmail.com

Proposed HAM - Outcome

Table 3.6: Effective embedding capacity [bits per pixel] and image quality (SSIM and PSNR [dB]) for the proposed method and its enhancements with respect to the Caltech 101 dataset

b_ε (%)	Effective Carrier Capacity					SSIM	PSNR [dB]
	Original	$\oplus 1$	Improvement [%]	$\oplus 2$	Improvement [%]		
1	**1.53**	0.83	-45.52	0.99	-34.85	0.0850	28.0438
2	2.78	2.09	-24.82	**2.88**	3.54	0.1235	28.6276
3	2.63	1.63	-37.96	**2.84**	7.97	0.1428	29.0242
4	2.29	1.27	-44.63	**2.55**	11.05	0.1577	29.3902
5	2.20	1.43	-35.15	**2.48**	12.63	0.1713	29.7153
6	2.04	1.50	-26.46	**2.33**	14.19	0.1839	30.0034
7	1.87	1.51	-19.47	**2.17**	15.95	0.1969	30.2897
8	1.75	1.53	-12.96	**2.05**	17.09	0.2099	30.5597
9	1.54	1.40	-9.10	**1.85**	19.88	0.2239	30.8046
10	1.49	1.46	-2.33	**1.80**	20.68		
20	0.68	0.93	37.79	**0.99**	45.41		
30	0.52	**0.79**	53.37	0.79	53.30		
40	0.27	**0.55**	103.28	0.52	92.19		
50	0.06	**0.29**	367.93	0.25	297.31		
60	0.06	**0.29**	377.85	0.25	303.40		
70	0.09	**0.31**	262.59	0.27	212.60		
80	0.12	**0.33**	175.73	0.29	143.45		
90	0.20	**0.36**	83.52	0.33	68.48		
100	0.01	**0.14**	1208.87	0.11	871.97		

Table 3.7: Comparison of embedding capacity [bits per pixel] for related works and proposed method using Lenna

b_ε (pixels)	512×512	256×256	128×128	64×64	32×32	16×16
Ni et al. Method [1]	0.0105	0.0185	0.0265	0.0404	0.0588	0.0853
Huang et al. Method [2]			0.0733			
Proposed Method	0.3089	0.5053	0.6829	0.8935	1.4636	2.1252

[1] Ni et al. Method (Ni et al., 2006) without subtracting the venue utilized to store peak point (i.e., side information).
[2] Huang et al. Method (Huang & Fang, 2011) without subtracting the venue utilized the block map (i.e., side information). Threshold utilized for composition is 0.29 and within the block size of 16, 32, and 64.

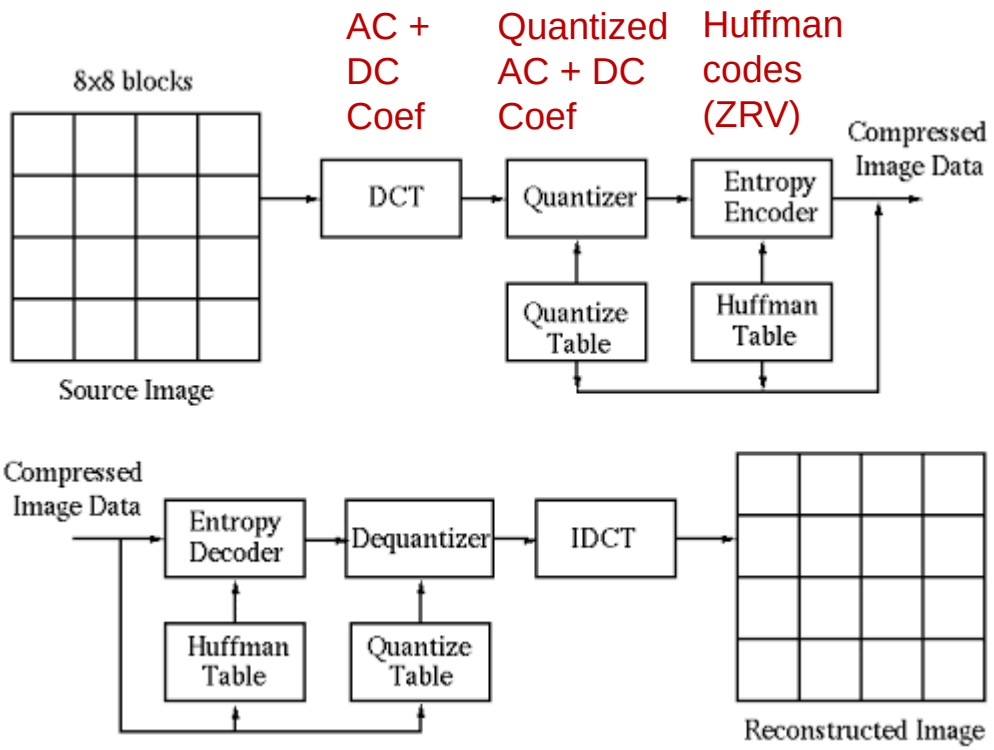
Unified IH in Compressed Signal Domain

References:

- **S. Ong,** K. Wong, and K. Tanaka, "Scrambling-Embedding for JPEG Compressed Image", 109(0), pp. 38-53, Signal Processing, April 2015.
- **S. Ong,** K. Wong, and K. Tanaka, "Reversible and Tunable Scrambling-Embedding Method", Intelligent Signal Processing and Communication Systems (ISPACS), pp. 608 – 613, 12 - 15 Nov. 2013.
- **S. Ong,** and K. Wong, "Rotational based Rewritable Data Hiding in JPEG", IEEE Visual Communications and Image Processing (VCIP), pp. 1-6, 17 - 20 Nov. 2013.
- **S. Ong,** K. Minemura and K. Wong, "Progressive Quality Degradation in JPEG Compressed Image using DC Block Orientation with Rewritable Data Embedding Functionality", International Conference on Image Processing (ICIP), pp. 4574-4578,15 - 18 Sept. 2013.

Compressed Signal Domain - JPEG

- Input: pixels
- Output: compressed signal (+- integers)



Can we propose a method using E2I approach? Is it possible?

simying.ong@um.edu.my
chaeyeng@gmail.com

Challenges: No key for encryption, the secret data determine the encryption pattern. How to decrypt?

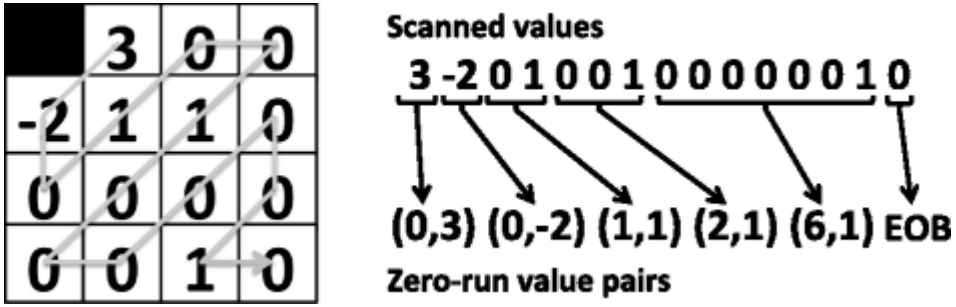
UIH E2I method using Natural Image Properties

NIP = Natural Compressed Signal Properties

simying.ong@um.edu.my
ongsimying@gmail.com

Compressed Signal Domain – JPEG

- Working on elements:
  - Quantized AC coefficients
  - Quantized DC coefficients
  - ZRV pairs



simying.ong@um.edu.my
ongsimying@gmail.com

Proposed Method (NIPC) – P1

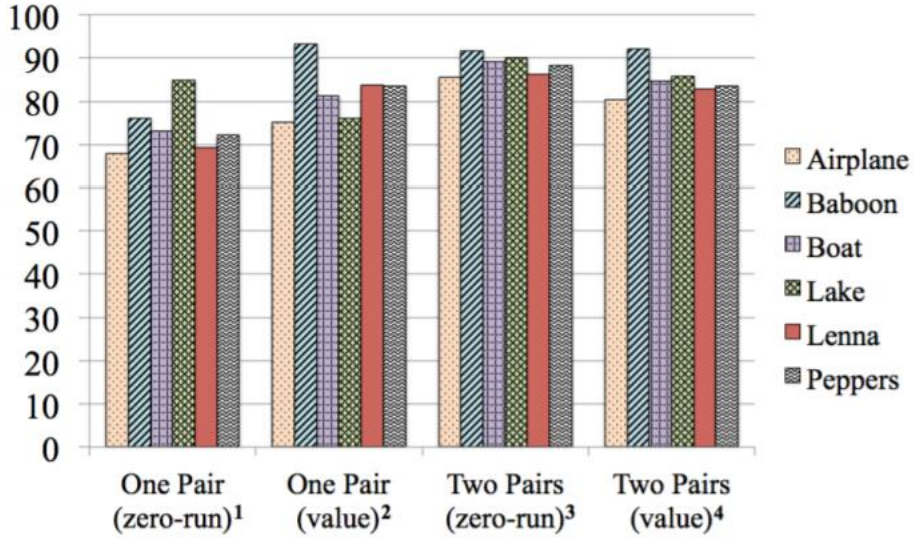


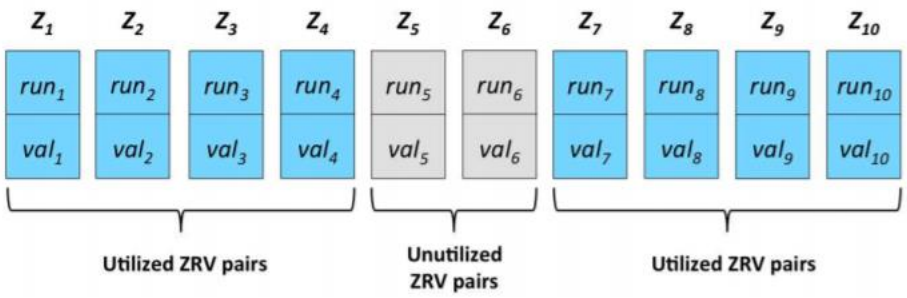
Figure 5.7: Statistics of ZRV properties [%] for six standard test images. [1]Zero-run of the first pair is smaller than zero-run of the last pair; [2]Magnitude of the first pair is larger than magnitude of the last pair; [3]Sum of zero-run for the first two pairs is smaller than the sum of zero-run for the last two pairs; [4]Sum of magnitude for the first two pairs is larger than the sum of magnitude for the last two pairs.

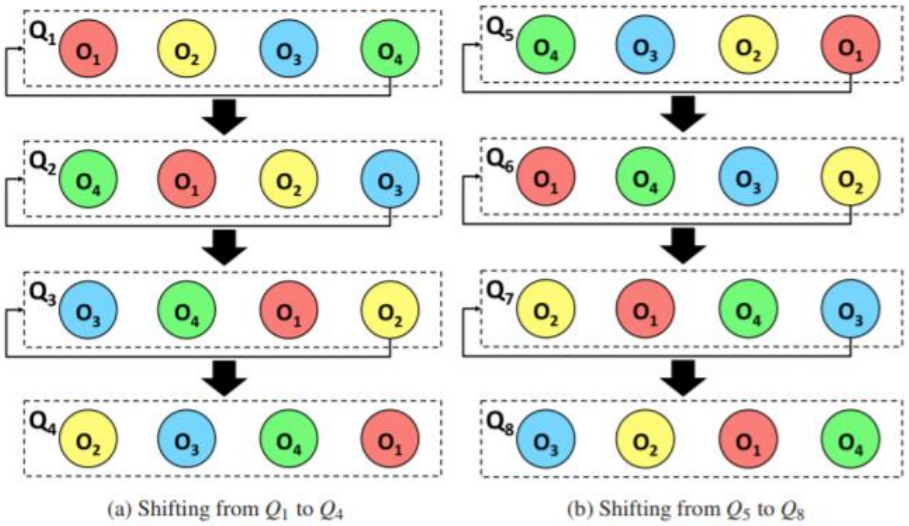
P1

The ZRV pairs in a quantized coefficient block have large magnitude and short zero-run for the front pairs while having small magnitude and long zero-run for the end pairs.

simying.ong@um.edu.my
ongsimying@gmail.com

Proposed Method (NIPC) – P1



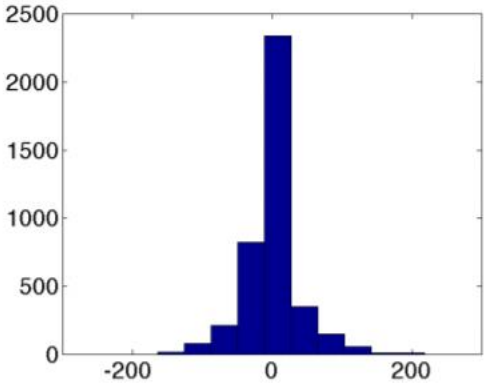


(a) Shifting from Q_1 to Q_4 (b) Shifting from Q_5 to Q_8

Figure 5.9: Illustration of ZRV groups shifting process for $d = 4$. Q_1 in (a) is flipped to produce Q_5 in (b).

Proposed Method (NIPC) – P2

(a) DC image



(b) Distribution of difference in DC values

Figure 5.11: Sketch of Lenna image using the DC coefficients and distribution of the difference between neighboring DC coefficients

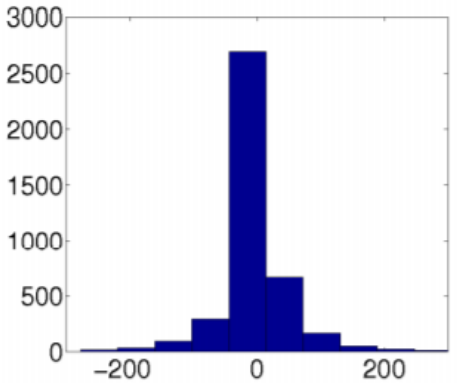


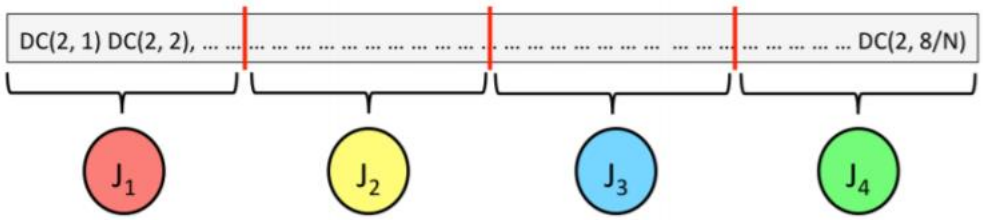
Figure 5.13: Distribution for difference in AC Block Energies in Lenna

P2	DC coefficients are highly correlated in both the horizontal and vertical directions.
P3	The sum of magnitude for quantized AC coefficient blocks are highly correlated in both the horizontal and vertical directions.

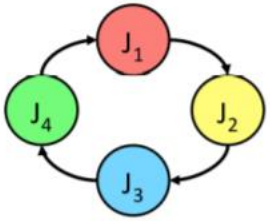
Proposed Method (NIPC) – P2

P2 DC coefficients are highly correlated in both the horizontal and vertical directions.

P3 The sum of magnitude for quantized AC coefficient blocks are highly correlated in both the horizontal and vertical directions.



(a) Division of DC coefficients into groups J_f

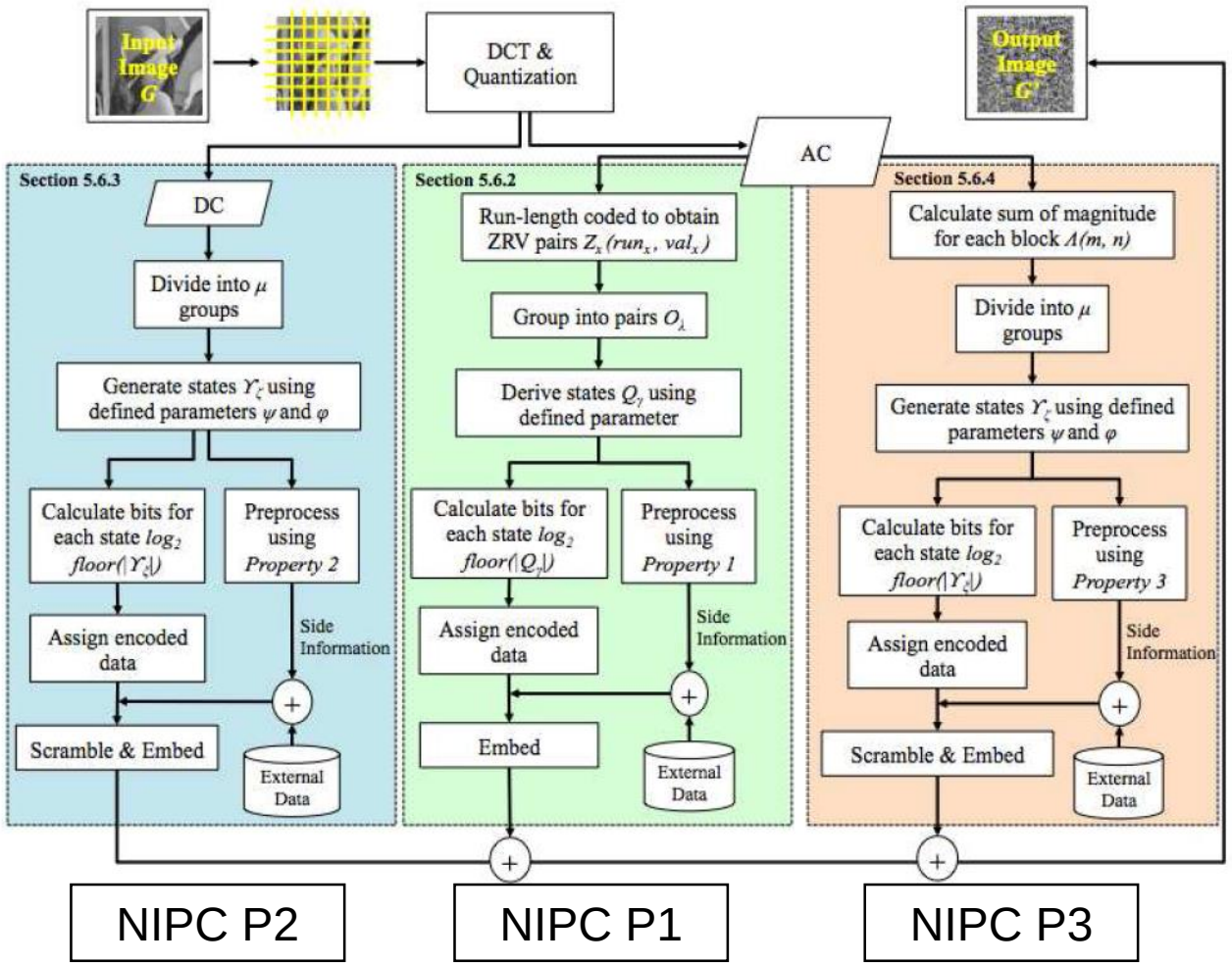


(b) Arranging DC groups in circular representation

Figure 5.12: Arrangement of DC coefficients groups

simying.ong@um.edu.my
ongsimying@gmail.com

Proposed Method (NIPC)



Outcome

- NIPC method can:
  - Suppress bitstream increment
  - Utilized all compressed signals for data embedding and encryption
  - Survive in Sketch Attack
  - Scalable, unified, reversible

EAC – Energy of AC coefficients attack
DCM – DC category mapping attack
NCC – Nonzero coefficients attack
PLZ – Position of Last Nonzero coefficient attack


(a) Original Image

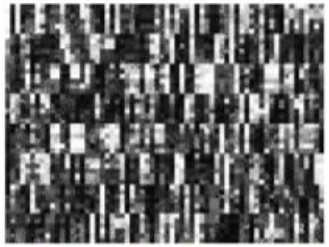

(b) NIPC1
($a_{gLim} = 16$)


(c) NIPC2 - G'_{R_o}
($\mu = 8$ & $\Psi = \text{Max}$)


(d) NIPC2 - $G'_{R_o \oplus C_o}$
($\mu = 8$ & $\Psi = \text{Max}$)

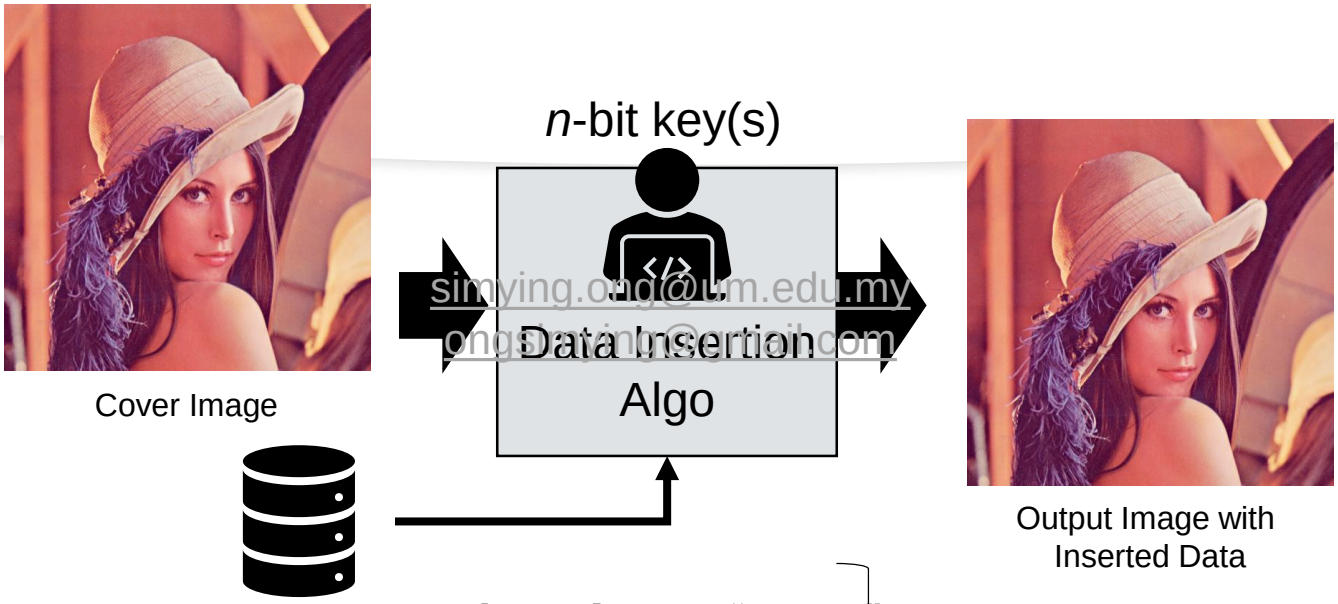

(e) NIPC3 - G'_{R_o}
($\mu = 8$ & $\Psi = \text{Max}$)


(f) NIPC3 - $G'_{R_o \oplus C_o}$
($\mu = 8$ & $\Psi = \text{Max}$)


(g) Proposed Combined Method

simying.ong@um.edu.my
ongsimying@gmail.com

Modern Image Data Insertion



- We always use **cover/carrier** to "carry" our secret data.
- BUT, **the use of cover image** creates many problems:
  - Limited embedding capacity
  - Comparison Attack
  - Statistical Attacks
  - Etc.

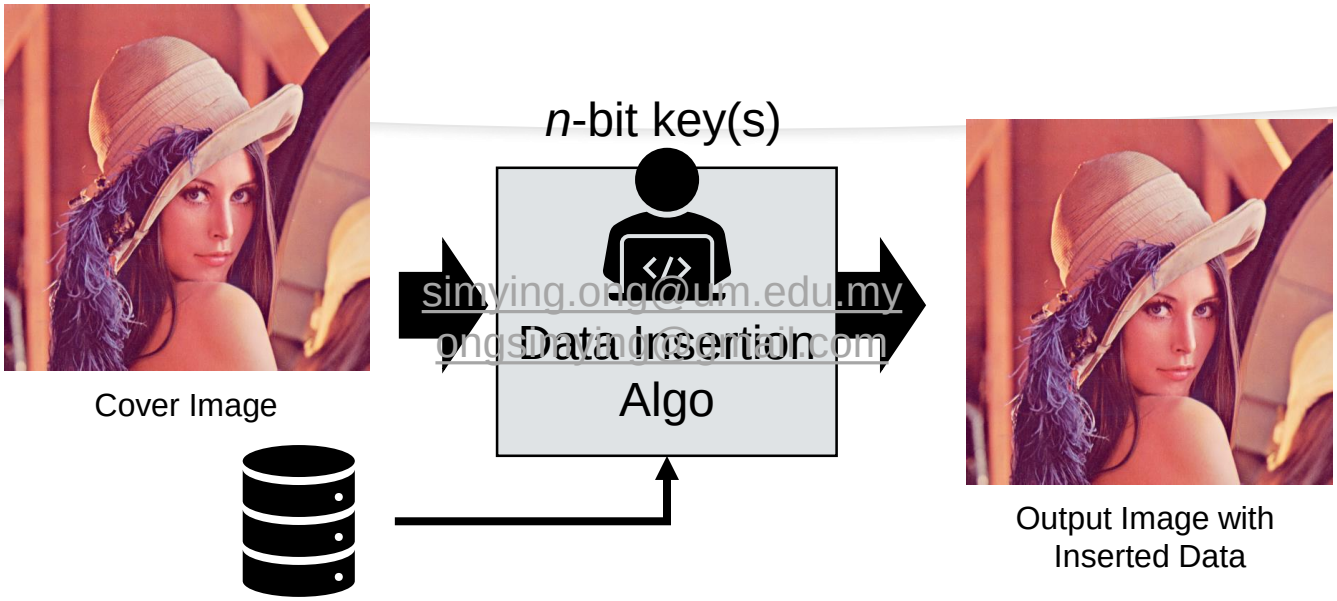
So, WHAT IF we don't use cover image?

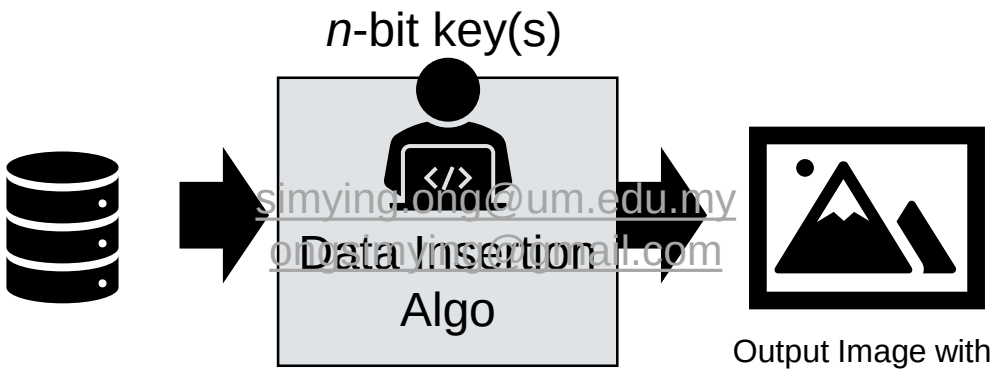
Coverless IH

References:

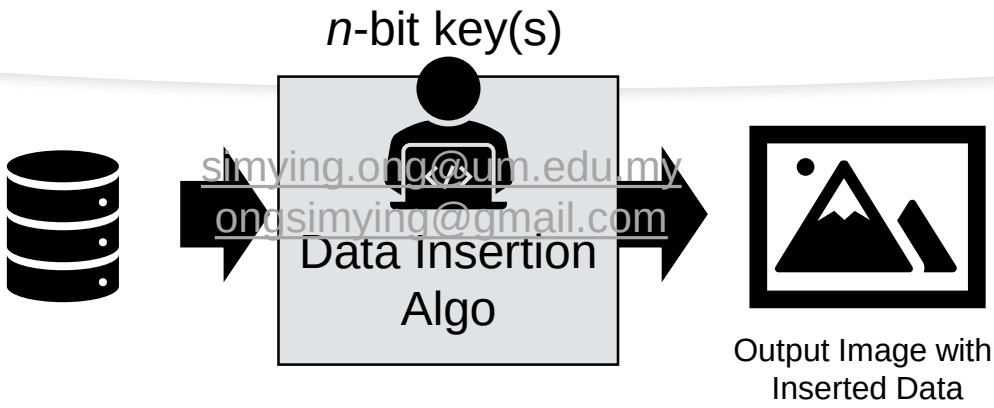
- W. K. Lee, S. Ong, K. Wong and K. Tanaka, "A Novel Coverless Information Hiding Technique Using Pattern Image Synthesis," 2018 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), Honolulu, HI, USA, 2018, pp. 1122-1127, doi: 10.23919/APSIPA.2018.8659777.

Proposed Coverless Framework





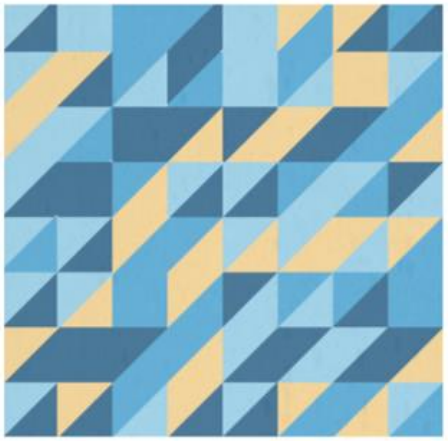
Conventional framework



- Proposed coverless IH using **pattern image generation**.
- Use image properties such as:
  - ✓Colours
  - ✓Sizes
  - ✓Position
  - ✓Direction
  - ✓Transparency
  - ✓Gap
- To represent secret data.

simying.ong@um.edu.my
ongsimying@gmail.com

Pattern Image Generation



(a)

(b)

(c)

(d)

simying.ong@um.edu.my
ongsimying@gmail.com

Can you guess which one has secret data?

Why coverless?

- It solves the problems mentioned earlier:
  - Embedding capacity is flexible – based on input size
  - No comparison and statistical attacks can be performed because there is original image and statistics.
- Secret data transmission / printing
- Aids QR code generation
  - Limited key-space
  - Bored design

simying.ong@um.edu.my
ongsimying@gmail.com

Photo Effects Embedding

References:

- S. Ong and K. Wong, “Information Hiding in Image Enhancement,” IEEE International Conference on Image Processing (ICIP), 2020. Accepted.
- W. W. Y. Kan, S. Ong, and K. Wong, "Data Embedding Method Using Photo Effects with Resistance to Compression," Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2020. Accepted.

The application and problem

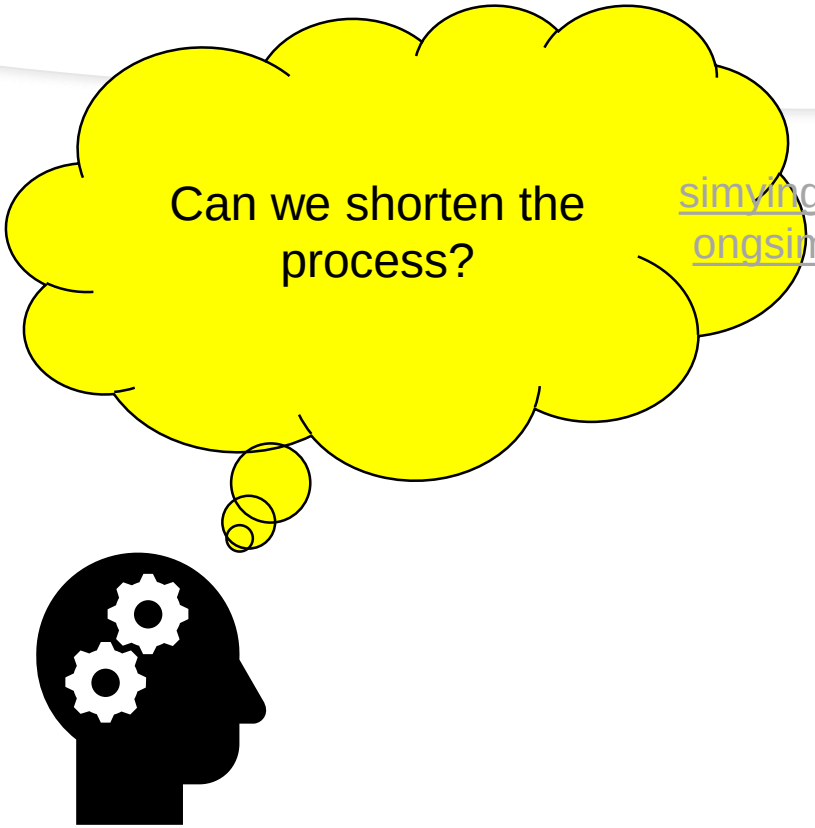
So many techniques in IH, why less usage?

Let's think from **USER** perspective:

- Capture image
- **If** I want to add watermark into my image
- Search for reliable tools
- Download and install the tool
- Learn to use the tool
- Use the tool to add watermark
- Beautify my image
- Share to Social Media

simying.ong@um.edu.my
ongsimying@gmail.com

The application and problem



Let's think from **USER** perspective:

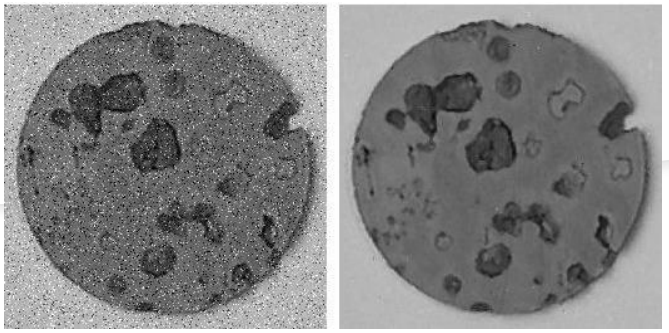
Capture image + watermark

[redacted]

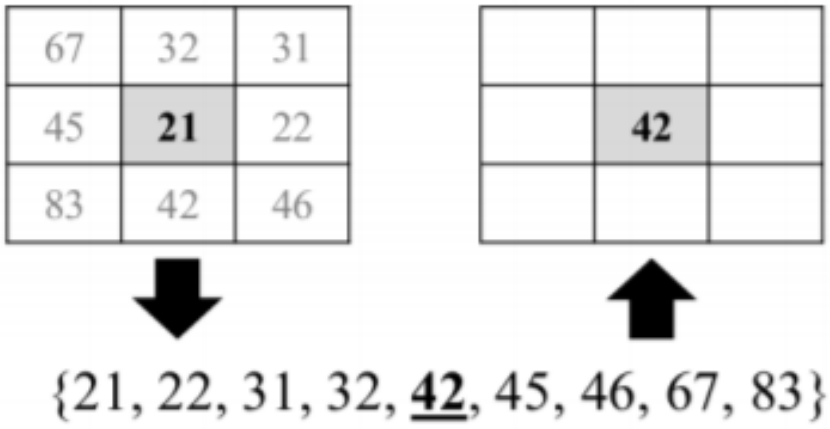
Beautify my image + watermark

Share to SNS + watermark

Image enhancement + watermarking



- Many mobile phone's camera comes with image enhancement feature.
- So, ***WHAT IF we can use image enhancement AND insert watermark at the same time?***
- To prove the concept, **MEDIAN FILTER** is used (noise removal).



Move in *nxn* sliding window manner.

Estimate/smoothen the pixel in the center location using the surrounding pixels.

Image enhancement + watermarking

{21, 22, 31, 32, 42, 45, 46, 67, 83} Standard Median Filtering

simying.ong@um.edu.my
ongsimying@gmail.com

{21, 22, 31, 32, 42, 45, 46, 67, 83} Divide into two partitions {0, 1}

{21, 22, 31, 32, 42, 45, 46, 67, 83} Divide into four partitions {00, 01, 10, 11}

Challenges:
a. Data extraction rate (won't deal with the original data)
b. Balance between embedding capacity and enhancement ability

Image enhancement + watermarking

simying.ong@um.edu.my
ongsimying@gmail.com

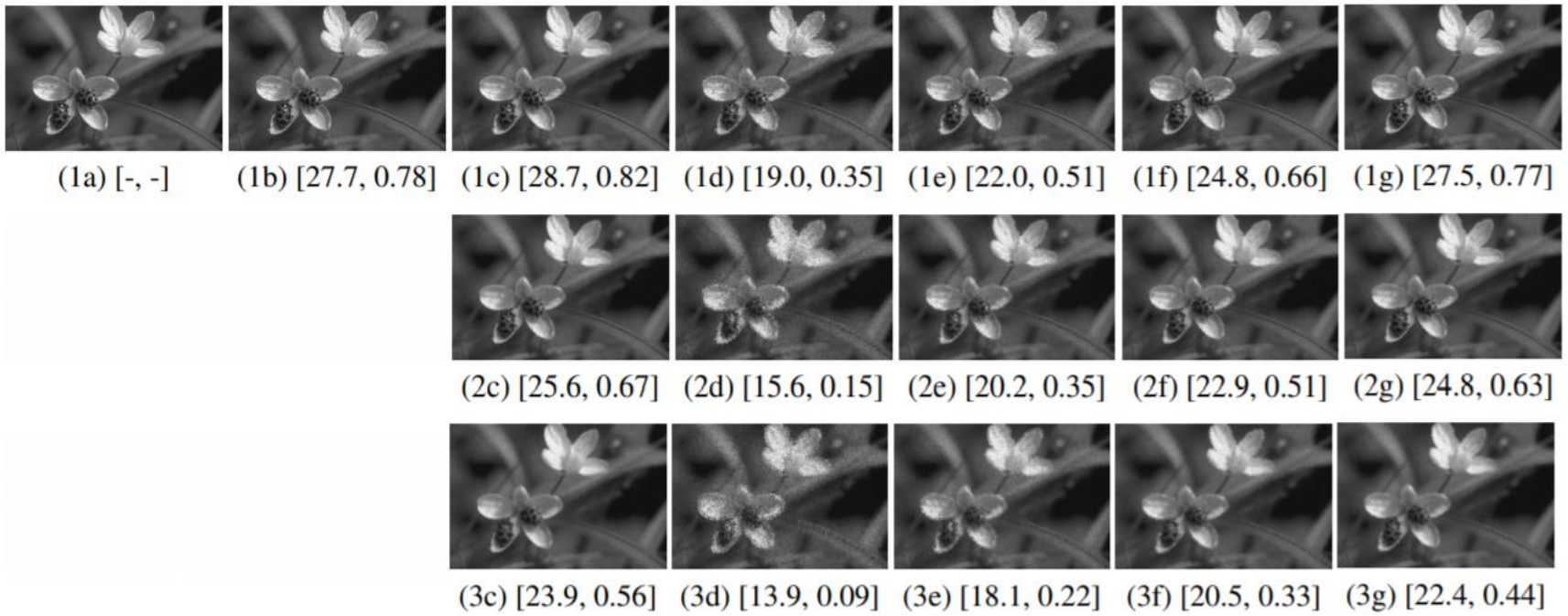
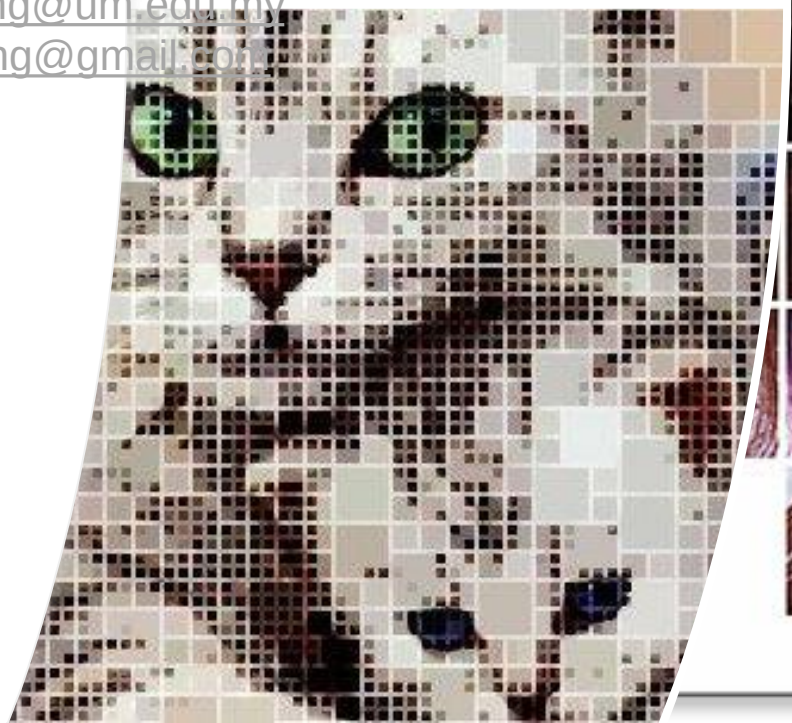


Fig. 2. Output images with Speckle noise (level = 0.01) added and their respective [PSNR, SSIM] values. Row 1 to Row 3 correspond to the output when $w = \{3, 5, 7\}$. Sub-figures 1(a) and 1(b) are the reference and generated-noise images, respectively. The third column shows Median-filtered image (without data embedding) for various w. Similarly, the forth to seventh columns show Median-filtered-embedded images with the pixel pair settings recorded in **Table 1**.

Photo effects + watermarking

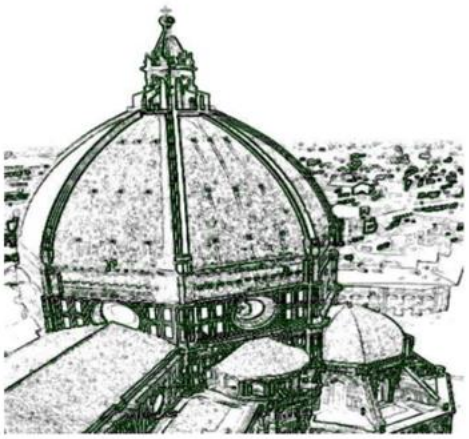
- Most of the users add photo effects before sharing their images online.
- Bokeh, mosaic, color grid, vintage, etc.



simying.ong@um.edu.my
ongsimying@gmail.com

Some of the works in progress…

Information hiding in photo effects



Sketch

Halftone

Vintage

simying.ong@um.edu.my
ongsimying@gmail.com

Conclusion

- **Image Processing**
  - Image vs visual
  - Image processing vs image analytic
  - Spatial domain vs frequency domain
  - Natural image properties
- **Unconventional Application – Information Hiding**
  - Encryption and data insertion
  - Applications – steganography, watermarking, etc.
  - Four different types of unified information hiding
  - I2S + histogram based method + spatial domain
  - E2S + NIP + frequency domain
  - Cover vs coverless information hiding
  - Photo effect embedding

Thank you!

Any questions?

simying.ong@um.edu.my