A New Scrambling Evaluation Scheme based on Spatial Distribution Entropy and Centroid Difference of Bit-plane

Liang Zhao *, † Avishek Adhikari ‡ Kouichi Sakurai *

* Graduate School of Information Science and Electrical Engineering, Kyushu University, Japan

†College of Computer Science, Chongqing University, China

‡ Department of Pure Mathematics, University of Calcutta, India

This research is supported by The Strategic Japanese-Indian Cooperative Programme on Multidisciplinary Research Field, which combines Information and Communications with Other Fields Supported by Japan Science and Technology Agency and Department of Science and Technology of the Government of India, and The Governmental Scholarship From China Scholarship Council (CSC).

zhaoliang@itslab.csce.kyushu-u.ac.jp

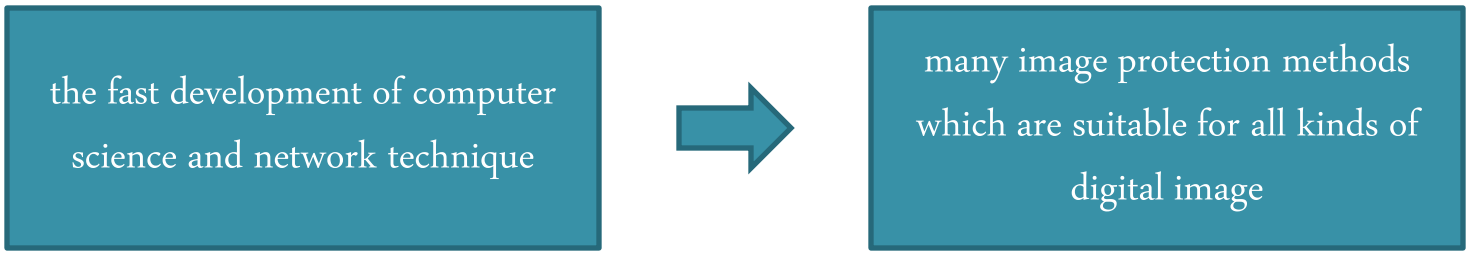
Outline

- Research Background
- Features of Bit-plane and Reason Why It Can Be Used
- Details Information of Scrambling Scheme
- Simulation Experiments on Proposed Scheme

zhaoliang@itslab.csce.kyushu-u.ac.jp

Research Background

- Reason:

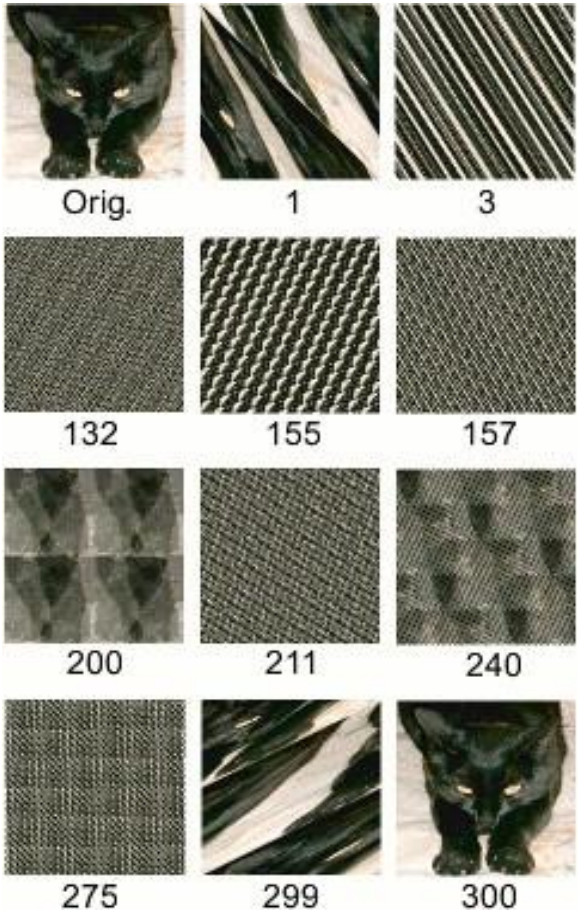


- (1) an elegant one-dimensional scrambling scheme based on the discrete prolate spheroidal sequences.(Wyner, IEEE transaction on information theory)
- (2) extended the above image scrambling algorithm to two-dimension. (Van De Viile et al., IEEE transaction on CS for video technology)
- (3) a chaotic image scrambling scheme making use of S-DES system.(Yu et al., Journal of Physics)
- (4) chaos theory and sorting transformation for design a image scrambling scheme.(Liu et al., International Journal of Computer Science and Network Security)

Research Background

- Typical image scrambling method:
  - Arnold cat map
  - Baker map
  - Fibonacci transformation
  - sub-affine transformation
  - ……

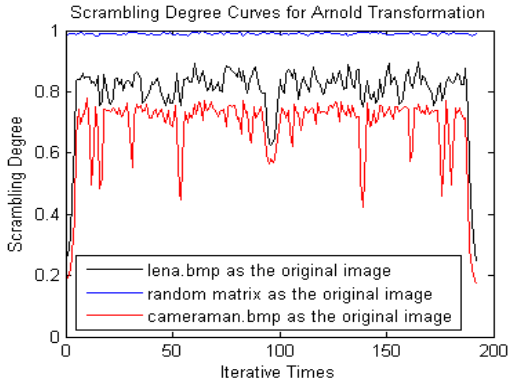
Generalized Arnold cat map



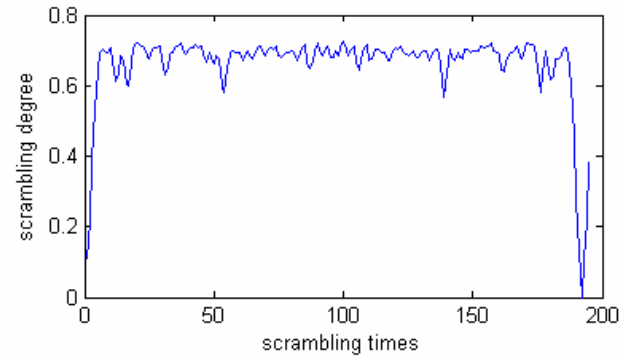
zhaoliang@itslab.csce.kyushu-u.ac.jp

Research Background

- Previous work
  - Li presents a measure for image scrambling degree which takes advantage of grey level difference and information entropy



  - Yu et al. use the correlation of pixels to analyze and evaluate the image scrambling



zhaoliang@itslab.csce.kyushu-u.ac.jp

Research Background

- Present Challenges
  - Pixel values and pixel positions
  - Evaluation results can reflect the character of image scrambling scheme
  - The scrambling degree should be independent of the plain image
  - Less image data can reflect the corresponding scrambling degree

Features of Bit-plane

- For any size of uncompressed digital image, if one pixel is located at the position of (x, y), the corresponding value of it can be denoted as $P(x, y)$.

- As the computer can only display discrete number according to its representation precision

for gray scale image, the pixel value is divided into 256 for the interval [0, 255].

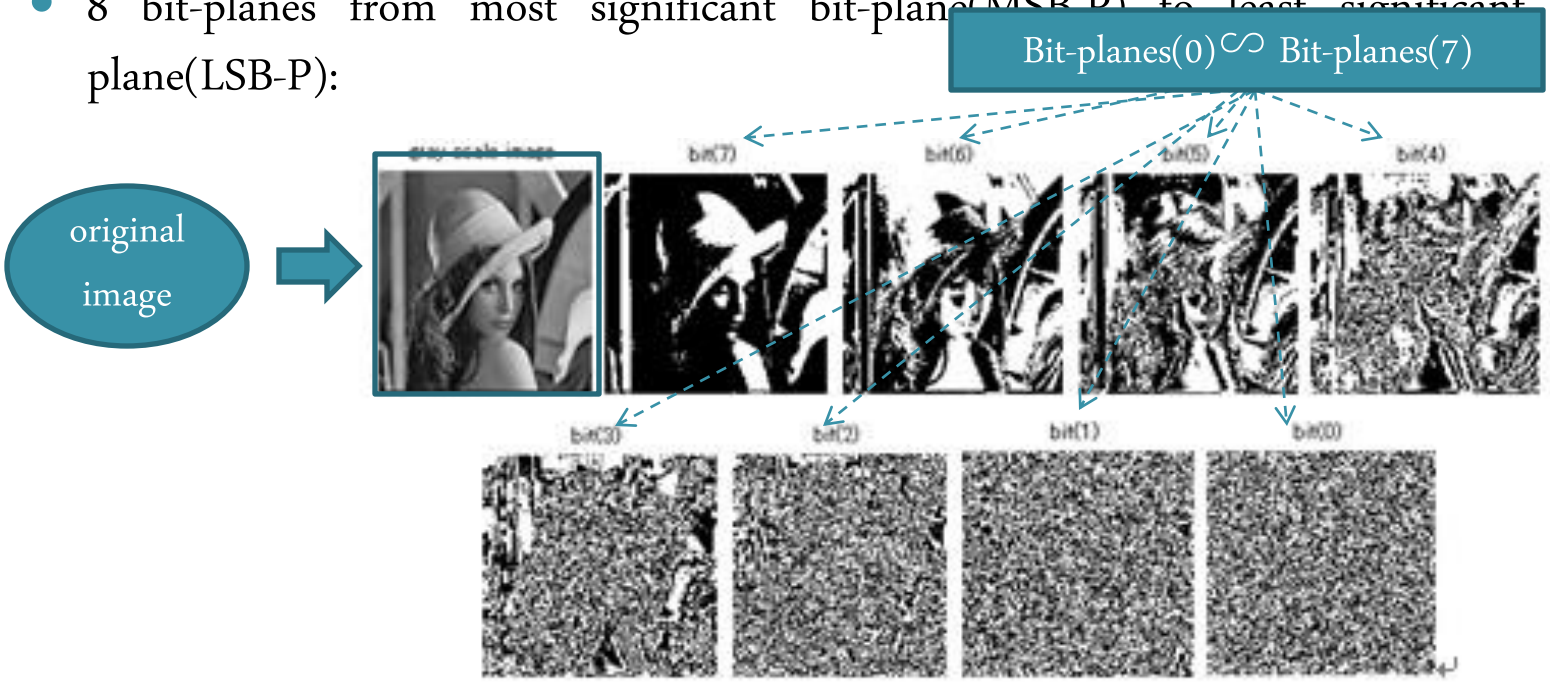
As the computer only deal with binary number, every pixel value is represented by 8 bits binary:

$$P(x, y)=\text{bit}(7)|\text{bit}(6)|\text{bit}(5)|\text{bit}(4)|\text{bit}(3)|\text{bit}(2)|\text{bit}(1)|\text{bit}(0)$$

$$\Rightarrow \text{bit}(0) \times 1+ \text{bit}(1) \times 2+ \text{bit}(2) \times 2 \times 2+\ldots\ldots+ \text{bit}(7) \times 2 \times 2\ldots$$

Features of Bit-plane

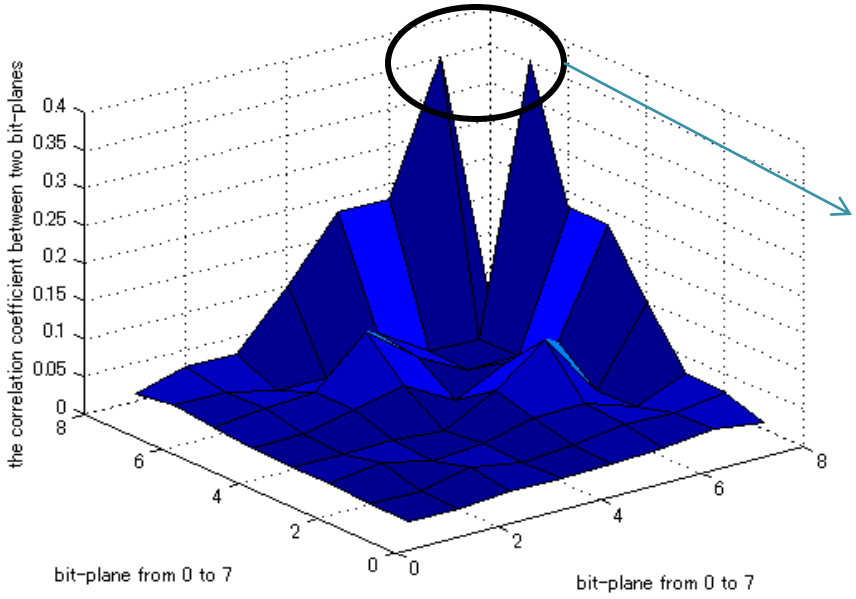
- 8 bit-planes from most significant bit-plane(MSB-P) to least significant bit-plane(LSB-P):



For every bit-plain, there is a different contribution to original gray image. The impact can increase when the bit-plane is from LSB-P to MSB-P.

Features of Bit-plane

- another important fact is that the relation between two adjacent bit-planes is also increase for the higher bit-planes.

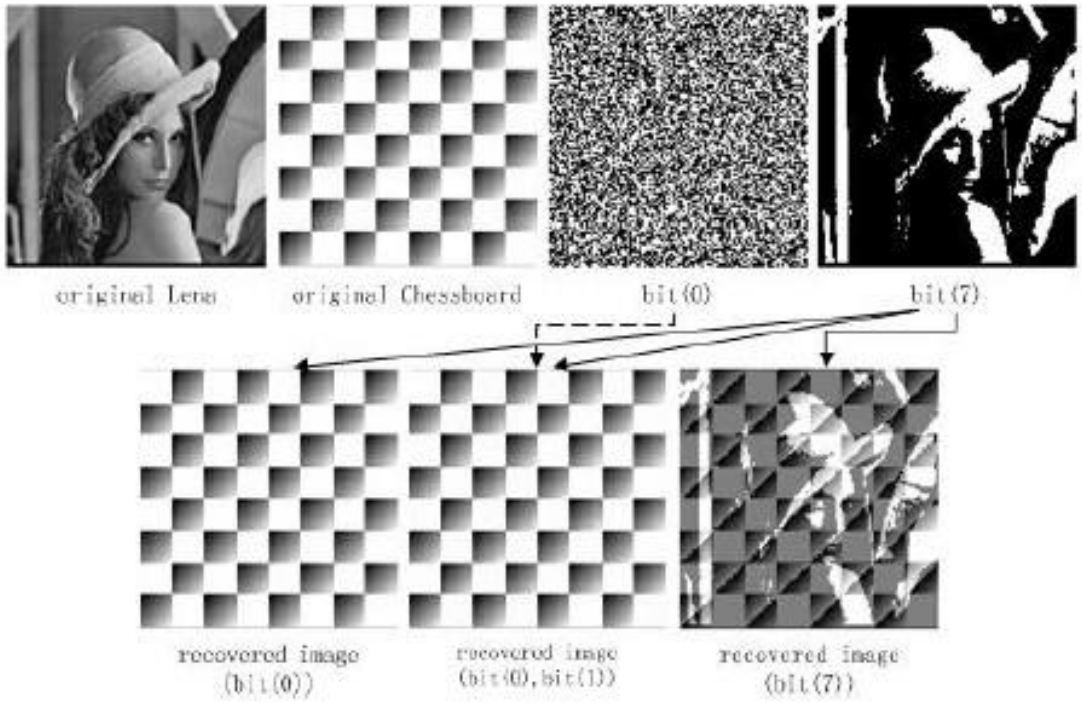


The relationship between bit-plane(6) and bit-plane(7)

zhaoliang@itslab.csce.kyushu-u.ac.jp

Features of Bit-plane

- for obtaining the relationship between gray-scale image and the corresponding bit-planes, such a test is done:



$$CS(i)=Ibit(i)/255$$
$$Ibit(i) \in \{128, 64, \ldots 1\}$$

zhaoliang@itslab.csce.kyushu-u.ac.jp

Why Bit-plain Can Be Used

- (1) Each bit-plane has an effect to original digital image. However, the impact of the bit-plane is different.

- (2) For the bit-plane, only 0 or 1 in each position of pixel. It can decrease the calculated amount, and the bit-plane is easy to deal with.

Details Information of Scrambling Scheme

- The Spatial Distribution Entropy of Digital Image

the distribution of 0 and 1 > the uncertainty of pixel values

- Sun et al. proposed spatial distribution entropy.

(Sun J, Ding Z, Zhou L. Image Retrieval Based on Image Entropy And Spatial Distribution Entropy. *J. Infrared Millim. Waves*. 24: 135-139, 2005)

  - on the assumption that there are N kind of pixel values

    $B_1, B_2, B_3, \ldots, B_N$, $S_q=\{(x, y)|(x, y) \in U, p(x, y) = B_q, q \in [1, N] \}$.

  - calculate the centroid of S_q, and ensure some ring cycles according to centroid and radius which produced by segmentation with equal distance or unequal distance.

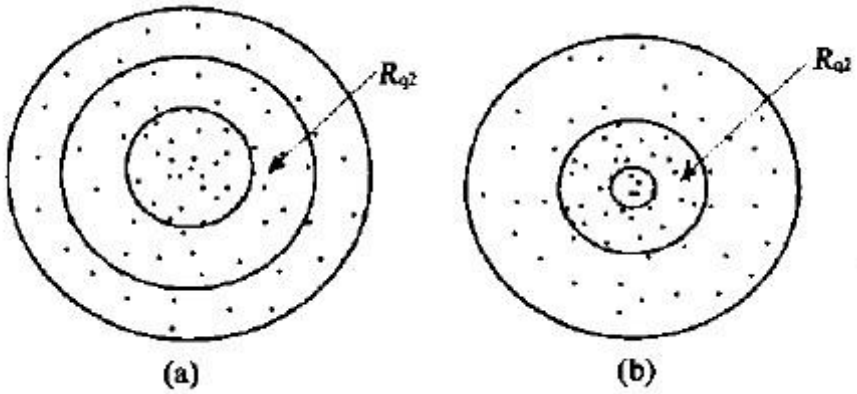
zhaoliang@itslab.csce.kyushu-u.ac.jp

Details Information of Scrambling Scheme

- Finally, for the pixel value B_q, the spatial distribution entropy can be expressed as:

$$E_q^s = -\sum_{j=1}^{k} p_{qj} \log 2^{(p_{qj})}$$

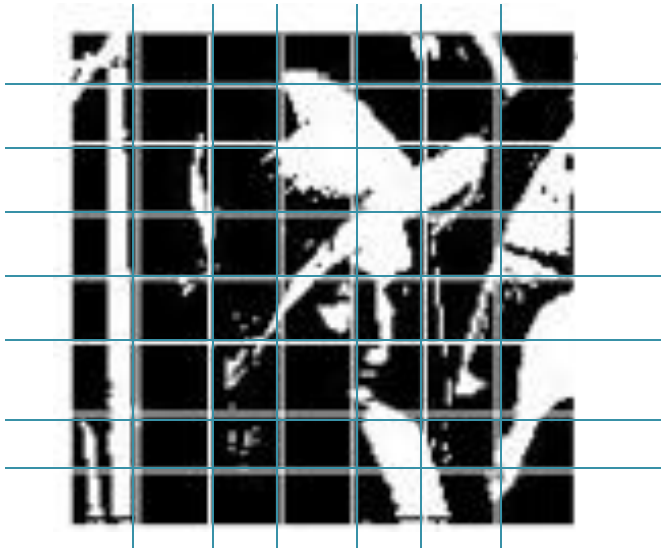
where k is the number of ring cycles, $p_{qj}=|R_{qj}|/|R_i|$, which is the probability density of B_q in ring cycle j. R_i is the number of B_q in S_q, R_{qj} is the number of B_q in ring cycle j.



Details Information of Scrambling Scheme

- In our scheme's cut:

Such as:



This average partition is applied in the bit-plane: {0,1,2,3,4,5,6,7} or {4,5,6,7}

zhaoliang@itslab.csce.kyushu-u.ac.jp

Details Information of Scrambling Scheme

- The Centroid Difference in Bit-plane

Centroid which is a math tool is always used in engineering application field, such as mechanical manufacturing, architecture design, computer graphics and so on.

(X_m, Y_m) is the corresponding centroid.

M_i is the quality of $M_i(x,y)$

(X_i, Y_i) is the location

$$X_m = \frac{\sum_{i=1}^{k} M_i X_i}{\sum_{i=1}^{k} M_i}; \qquad Y_m = \frac{\sum_{i=1}^{k} M_i Y_i}{\sum_{i=1}^{k} M_i}$$

For the bit-plane, we can suppose that each pixel has 'quality'-0 or 1.That is to say, for every block, the corresponding Centroid can be calculated as:

$$X_m^{rg} = \frac{\sum_{i=1}^{h} X_i}{\sum_{i=1}^{h} n_i}; \qquad Y_m^{rg} = \frac{\sum_{i=1}^{h} Y_i}{\sum_{i=1}^{h} n_i}$$

Details Information of Scrambling Scheme

- The Centroid of whole image is acquired by the following:

$$X_m^g = \frac{\sum_{t=1}^{r}(\sum_{i=1}^{h} n_i X_m^{rg})^t}{\sum_{t=1}^{r}(\sum_{i=1}^{h} n_i)^t}; \qquad Y_m^g = \frac{\sum_{t=1}^{r}(\sum_{i=1}^{h} n_i Y_m^{rg})^t}{\sum_{t=1}^{r}(\sum_{i=1}^{h} n_i)^t}$$

- Therefore, the Centroid difference is express as:

$$diffva_g = \sqrt{(X_m^g - X_c^g)^2 + (Y_m^g - Y_c^g)^2}$$

zhaoliang@itslab.csce.kyushu-u.ac.jp

Details Information of Scrambling Scheme

- The scrambling degree is based on the above Spatial Distribution Entropy and Centroid difference.
- The final value of scrambling degree(*scraderee*) is calculated as following:

$$scraval^{g} = \frac{\text{Spatial Distribution Entropy}}{\text{Centroid difference}}$$

$$scraderee = \sum_{g=0/4}^{7} w(g) \cdot scraval^{g}; \qquad g \in \{0,1,2,3,4,5,6,7\}$$

zhaoliang@itslab.csce.kyushu-u.ac.jp

Details Information of Scrambling Scheme

- $w(g)$ is the corresponding weight for *scraderee*:

(1) For 8-bit plane:

$CS(i)$ is the weight. $i \in \{0,1,2,3,4,5,6,7\}$

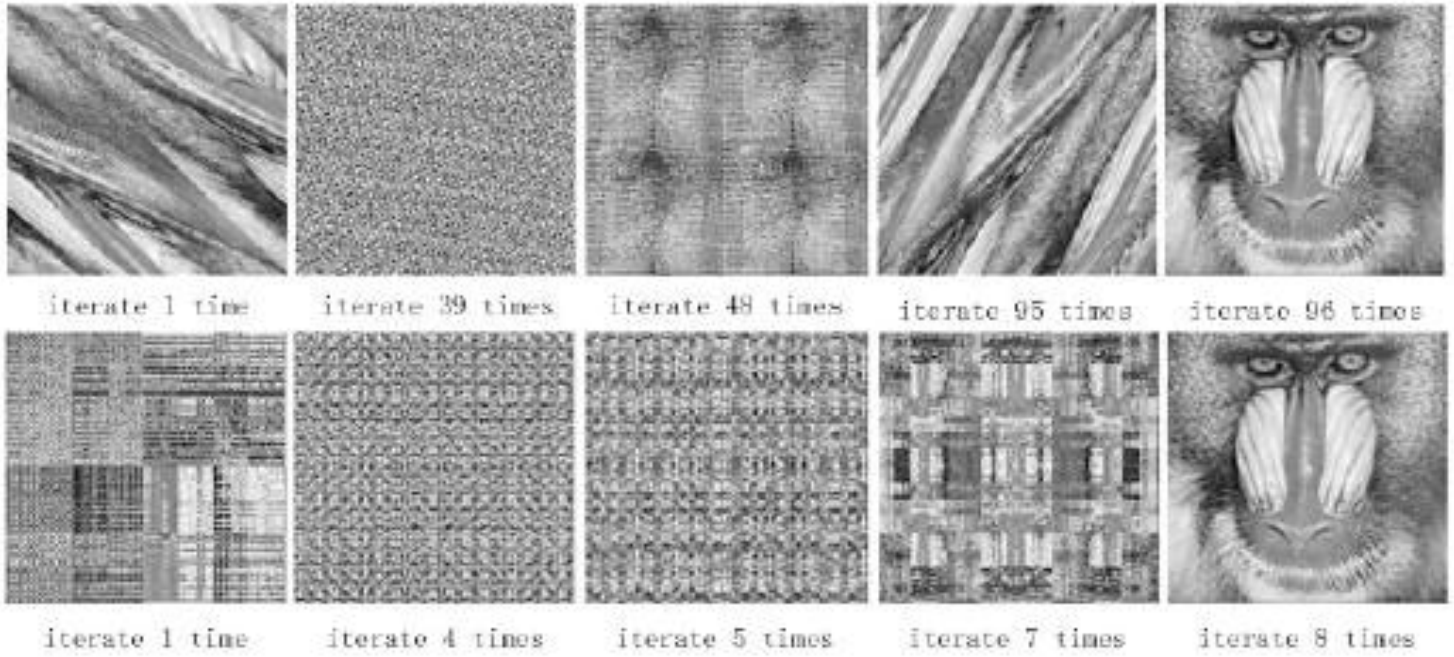
(2) For 4-bit plane:

$$\begin{cases} w(7)+w(6)+w(5)+w(4)=1 \\ w(6)=|r(6,7)| \times w(7) \\ w(5)=|r(5,7)| \times w(7) \\ w(4)=|r(4,7)| \times w(7) \end{cases}$$

zhaoliang@itslab.csce.kyushu-u.ac.jp

Simulation Experiments on Proposed Scheme

- Two typical scrambling map:
  - Arnold cat map
  - Generalized Gray code



zhaoliang@itslab.csce.kyushu-u.ac.jp

Simulation Experiments on Proposed Scheme

- The following four images are used in the proposed scheme: “Baboon”, “Boat”, “Internetgirl” and “Landscape”.


Baboon


Boat

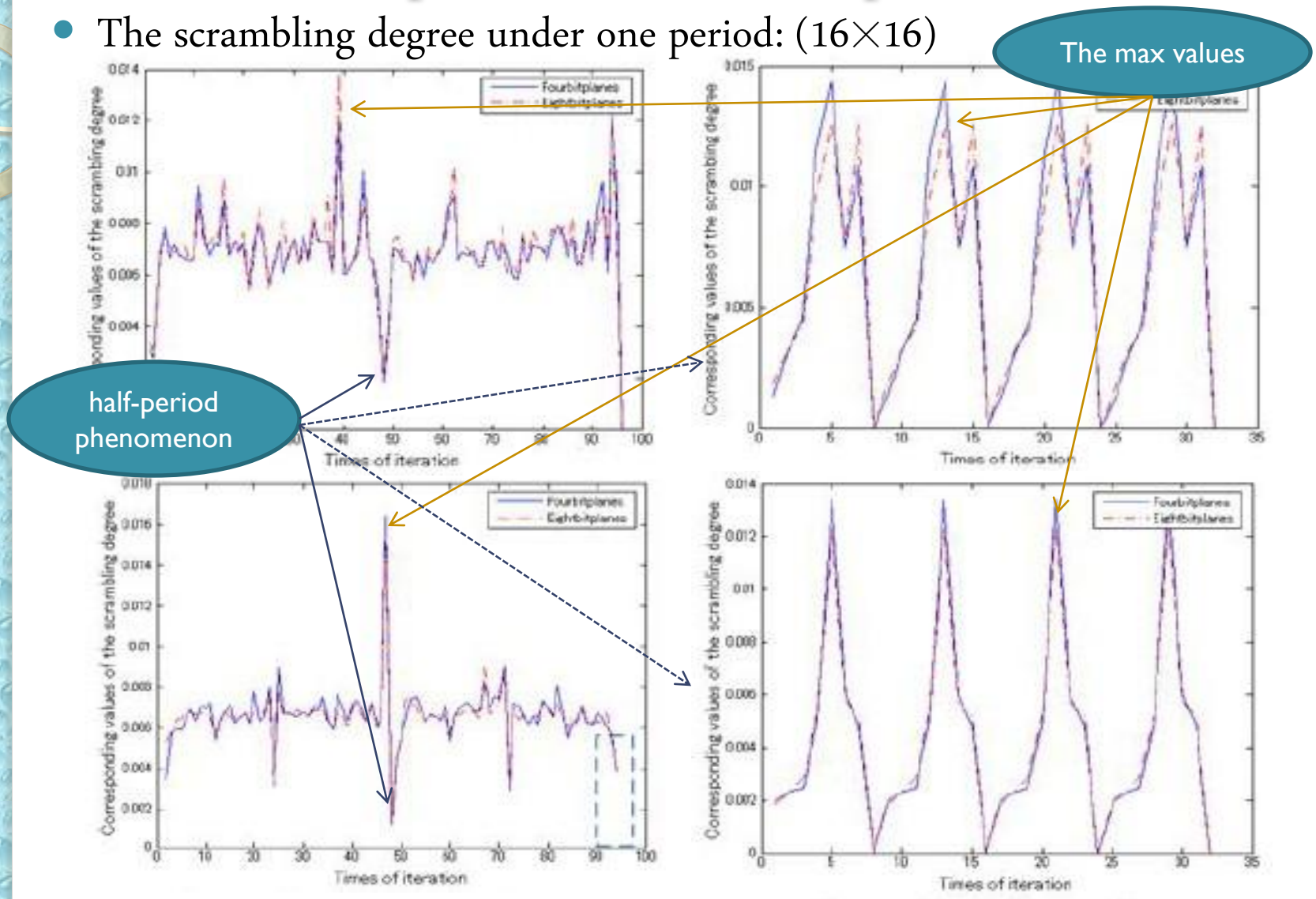

Internetgirl


Landscape

zhaoliang@itslab.csce.kyushu-u.ac.jp

Simulation Experiments on Proposed Scheme

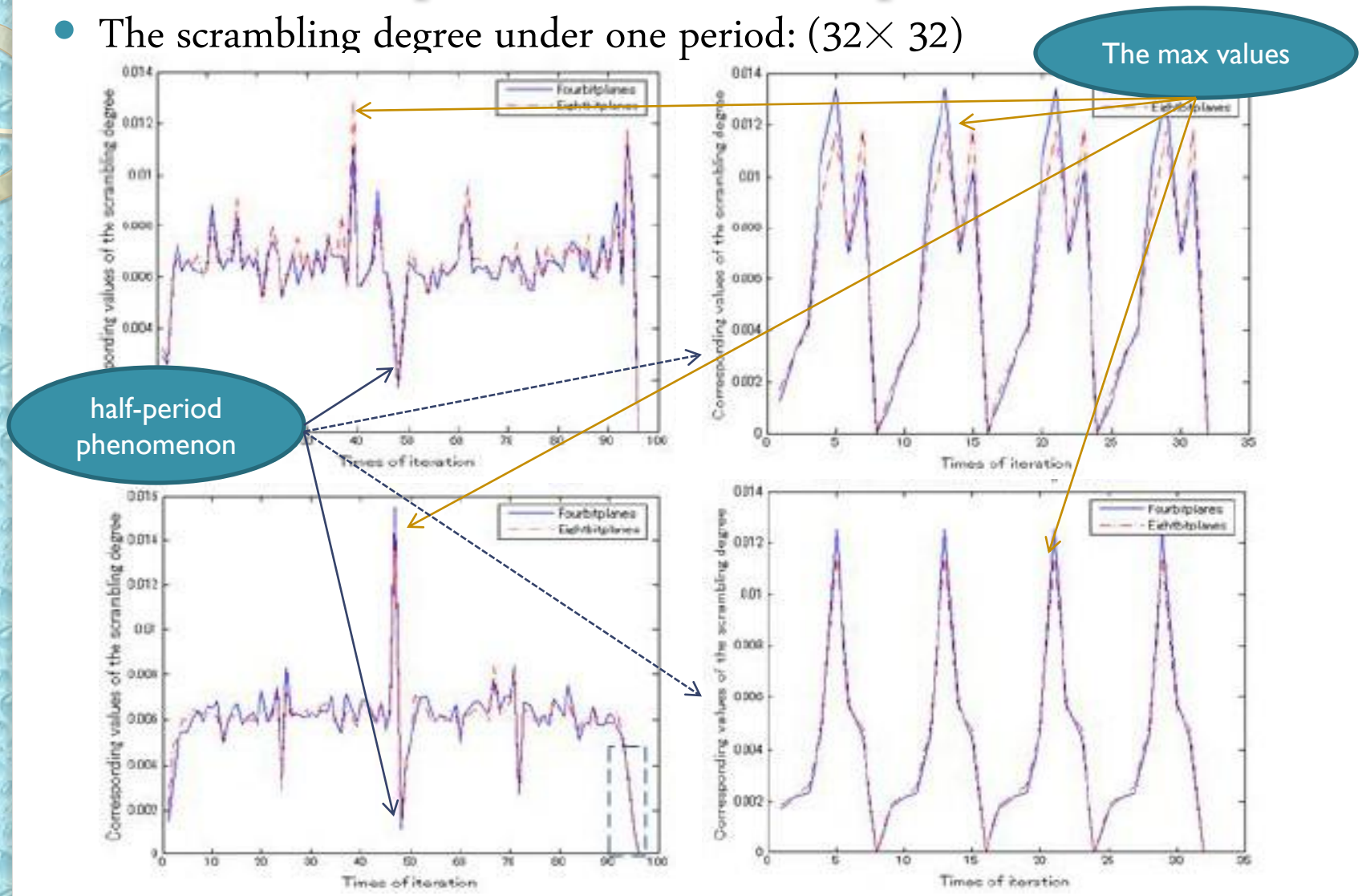
- The scrambling degree under one period: (16×16)



zhaoliang@itslab.csce.kyushu-u.ac.jp

Simulation Experiments on Proposed Scheme

- The scrambling degree under one period: (32× 32)



zhaoliang@itslab.csce.kyushu-u.ac.jp

Simulation Experiments on Proposed Scheme

- Some phenomenon are presented:

1. The max and min scrambling degree to demonstrate the iteration number.

2. Half-period phenomenon in the scrambling transformation with a long period.

3. The scrambling degree in 4-bit planes and 8-bit planes.

Conclusions

- One scrambling evaluation scheme is given
- 8 bit-planes or 4 bit-plains are used in our evaluation system.

  The scrambling degree can be the same for some gray-scale image
- The spatial distribution entropy of digital image and centroid difference in bit-plane are used for texting the scrambling degree

Thank you very much, every researcher