containing hidden data according to the data-hiding key. Since the data embedding only affects the LSB, a decryption with the encryption key can result in an image similar to the original one. When using both of the encryption and data-hiding keys, the embedded data can be successfully extracted and the original image can be recovered without any loss by exploiting the spatial correlation in natural image.

A. Image Encryption

Assume the original image with a size of *N1 X N2* is in uncompressed format and each pixel with gray value falling into [0, 255] is represented by 8 bits.

Denote the gray value as $P_{i,j}$, where *i,j* indicates the pixel position, and bits of a pixel as $b_{i,j,0}$, $b_{i,j,1}$,..., $b_{i,j,7.}$ The gray value is converted into bits.

$$b_{i,j,k} = \left\lfloor \frac{P_{i,j}}{2^k} \right\rfloor \bmod 2, \quad k=0,1,\ldots,7$$

8 bit representation of each pixel of an image is encrypted by performing XOR with the $r_{i,j,k}$ which is determined by an encryption key to create a cover image.

$$B_{i,j,k} = b_{i,j,k} \oplus r_{i,j,k}$$

B. Data Embedding

In this phase, three parameters are embedded into a small number of encrypted pixels, and the LSB of the other encrypted pixels are randomly permuted and compressed to form a partition matrix $PM_{i,j}$ to create a space for accommodating the data by the proposed FCM-DH algorithm.

Algorithm: FCM-DH

Inputs *CI cover (encrypted) image, $D_{[1,\ldots n]}$ data, and K data-hiding key*
Output *image, containing data.*
Initialize *parameters M,PL and I*
Select *N_p/N pixels from CI* ⟵ *parameters*
op ⟵ *$[N\text{-}N_p]^{p(k)}$*
G ⟵ *[N-Np]/PL*
i ⟵ *1*
Do
for *j=1 to PL*
  for *k=1 to M*
    $LSB_{i,j}$ ⟵ *$B_{j,k}$*
  end
end
$cbits_{i,1..M.PL-I}$ ⟵ *$LSB_{i,1,\ldots,}$ $LSB_{i,M.PL-I}$*
$PM_{i,1\ldots I}$ ⟵ *$LSB_{i,M.PL-I+1}, \ldots\ldots, LSB_{i,M.PL}$*
Repeat *group i to G*
$PM_{i\ldots G,1\ldots I}$ ⟵ *$[asci(D_{[1,\ldots.n]})]/2^k \bmod 2$, k=1,..,7*
op ⟵ *$[N\text{-}N_p]^{\sim p(k)}$*
return *CI containing $D_{[1,\ldots\ldots,n]}$*

C. Data Extraction and Image Recovery

In this phase, consider the three cases that a receiver has only the data-hiding key, only the encryption key, and both the data-hiding and encryption keys, respectively. Note that because of the random pixel selection and permutation, any attacker without the data-hiding key cannot obtain the parameter values and the pixel-groups, therefore cannot extract the embedded data.

Furthermore, although the receiver having the data-hiding key can successfully extract the embedded data by the inverse process of FCM-DH technique, but cannot get any information about the original image content. Similarly recover the image with encryption key. When the receiver has both of the keys, can extract the data and recover the original content of a cover image without any error by exploiting the spatial correlation in natural image.

III. RESULTS AND DISCUSSION

The test image Koala.jpg sized 300 x 300 shown in Fig.1 (a) was used as the cover image in the experiment. After image encryption, the eight encrypted bits of each pixel are converted into a gray value to generate an encrypted image shown in Fig.1 (b). The data can embedded into an encrypted image using FCM-DH algorithm is shown in Fig.1(c). With an encrypted image containing embedded data, we could extract the data using the data-hiding key. If we directly decrypted the encrypted image containing embedded data using the encryption key, the directly decrypted image is given in Fig.1 (d)

Fig. 1(a)

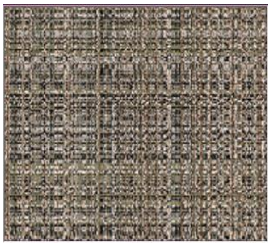

Fig. 1(b)

Fig. 1(a) Original Koala.jpg sized (300 x 300)
Fig. 1(b) Encrypted image

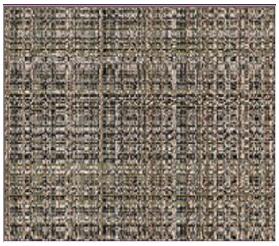

Fig. 1(c)

Fig. 1(d)

Fig. 1(c) Image containing data (result from FCM_DH algorithm)
Fig. 1(d) Directly decrypted image

By using both the data-hiding and the encryption keys, the embedded data could be successfully extracted and the original image could be perfectly recovered from the encrypted image containing embedded data.

IV. CONCLUSION

In this paper, a novel FCM-DH algorithm for in-dependable data hiding in an encrypted image is proposed, which consists of image encryption, data embedding and data-extraction/image-recovery phases. Therefore the pixels of an encrypted image are compressed by form a partition matrix to create a space to accommodate data. With an encrypted image containing data, the receiver may extract the additional data using only the data-hiding key, or obtain an image similar to the original one using only the encryption key. When the receiver has both of the keys, he can extract the data and recover the original content of an image.

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