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SCFformer: a binary data hiding method against JPEG compression based on spatial channel fusion Transformer

Key words: Binary data hiding; Against JPEG compression; Discrete cosine transform quantization; SCFformer

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Motivation

- Targeting the inadequacy of current data hiding algorithms, which exhibit significant extraction errors after low-quality-factor JPEG compression and demonstrate limited practical applicability, a novel anti-JPEG compression binary data hiding method based on spatial channel fusion Transformer (SCFformer) is proposed, which can recover secret information with high precision after image processing.

Main idea

- A novel anti-JPEG compression binary data hiding method based on SCFformer is proposed, which can provide high-precision secret information recovery with a low quality factor.
- A discrete cosine transform (DCT) quantization truncation mechanism is proposed, which improves the anti-JPEG compression ability of stego images, improves the flexibility by using the scalable module, and realizes secret data hiding with variable capacity.
- An efficient fusion Transformer is proposed, which improves the ability of capturing the dimensional relationships of the entire space and channels while maintaining high efficiency, thereby achieving a lower secret data extraction error rate (ER) at the same capacity.

Method

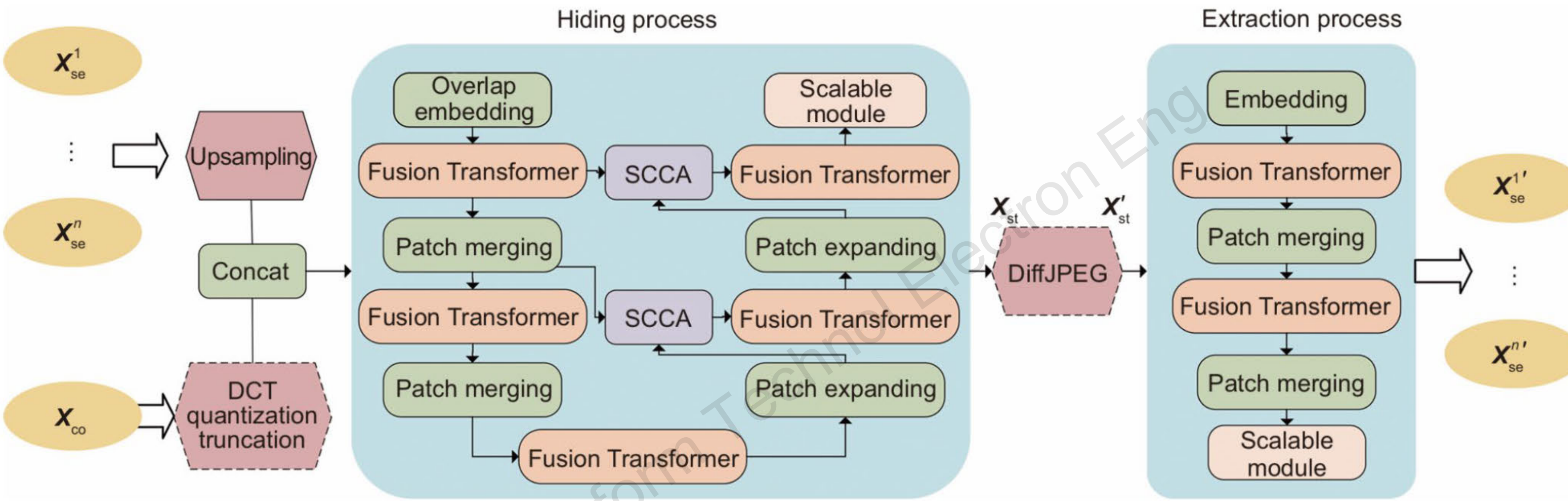

Fig. 1 The overall framework of SCFformer data hiding scheme including mainly two parts, hiding process and extraction process

$$\begin{cases} \boldsymbol{T}(\boldsymbol{Q},\boldsymbol{K},\boldsymbol{V}) = \boldsymbol{V}\boldsymbol{C}_{\mathrm{T}}(\boldsymbol{K},\boldsymbol{Q}), \\ \boldsymbol{C}_{\mathrm{T}}(\boldsymbol{K},\boldsymbol{Q}) = \mathrm{Softmax}\left(\dfrac{\boldsymbol{K}^{\mathrm{T}}\boldsymbol{Q}}{\tau}\right), \end{cases}$$

Learning process can be described as

$$\begin{cases} \boldsymbol{E}_{\mathrm{block}}(\boldsymbol{X},\boldsymbol{Q}_1,\boldsymbol{K}_1,\boldsymbol{V}_1) = \boldsymbol{E}(\boldsymbol{Q}_1,\boldsymbol{K}_1,\boldsymbol{V}_1) + \boldsymbol{X}, \\ \mathrm{MF}_1(\boldsymbol{E}_{\mathrm{block}}) = \mathrm{MF}(\mathrm{LN}(\boldsymbol{E}_{\mathrm{block}})), \\ \boldsymbol{T}_{\mathrm{block}}(\boldsymbol{E}_{\mathrm{block}},\boldsymbol{Q}_2,\boldsymbol{K}_2,\boldsymbol{V}_2) \\ \quad = \boldsymbol{T}(\mathrm{MF}_1(\boldsymbol{E}_{\mathrm{block}}) + \boldsymbol{E}_{\mathrm{block}}) + \mathrm{MF}_1(\boldsymbol{E}_{\mathrm{block}}), \\ \mathrm{MF}_2(\boldsymbol{T}_{\mathrm{block}}) = \mathrm{MF}(\mathrm{LN}(\boldsymbol{T}_{\mathrm{block}})), \\ \mathrm{FT}(\boldsymbol{T}_{\mathrm{block}}) = \mathrm{MF}_2(\boldsymbol{T}_{\mathrm{block}}) + \boldsymbol{T}_{\mathrm{block}}. \end{cases} \quad (3)$$

Method

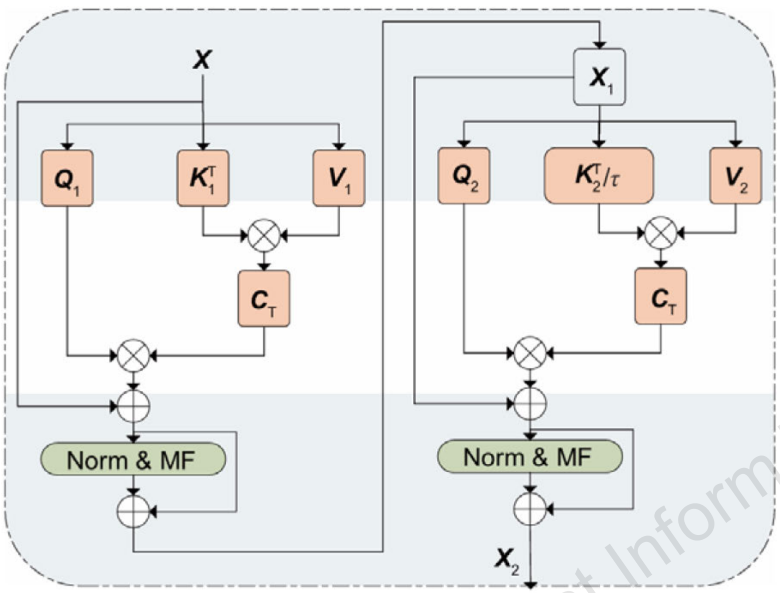

Fig. 2 Efficient fusion Transformer module including an efficient spatial attention block and a channel attention block, followed by a specification and mix-feedforward (MF) neural network

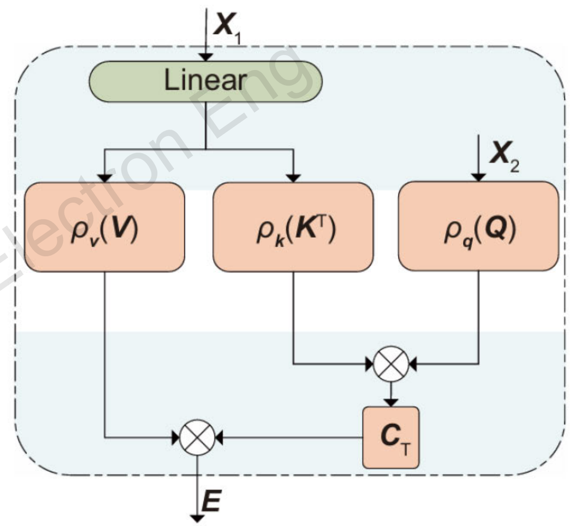

Fig. 3 The SCCA module containing a linear layer and an efficient attention module

Results

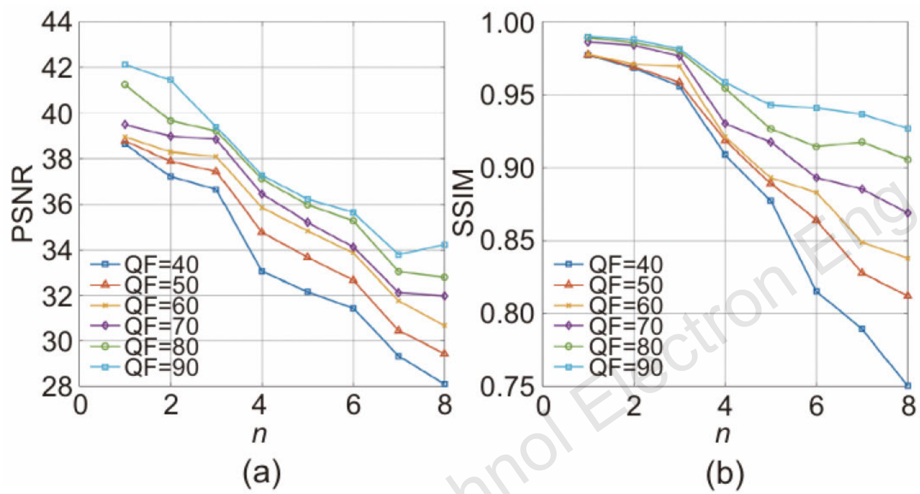

Fig. 8 PSNR (a) and SSIM (b)

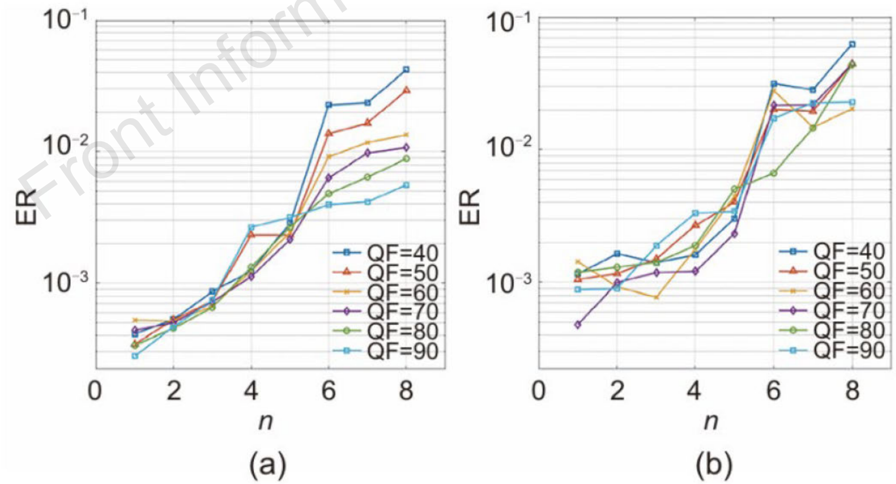

Fig. 9 Error rate (ER) under different n's using SCF-former (a) and U-Net (b)

Results

Table 4 Generalization performance results in four datasets

Dataset	Type	MSE	ER	PSNR		SSIM	
				Max	Average	Max	Average
ImageNet1K	Variation A	0.000 180	0.000 721	45.77	38.85	0.990	0.976
	Variation B	0.000 195	0.000 972	43.29	38.12	0.986	0.967
	Variation C	0.000 572	0.001 216	41.33	33.61	0.978	0.928
CelebA	Variation A	**0.000 064**	**0.000 139**	**46.06**	**42.91**	0.990	**0.980**
	Variation B	0.000 090	0.000 140	43.68	41.12	0.983	0.968
	Variation C	0.000 198	0.000 420	42.33	37.98	0.974	0.954
DIV2K	Variation A	0.000 222	0.000 801	43.91	38.40	0.988	0.978
	Variation B	0.000 241	0.000 725	41.48	36.97	0.988	0.971
	Variation C	0.000 741	0.001 615	38.14	32.09	0.973	0.933
MS-coco	Variation A	0.000 172	0.000 801	45.58	39.35	**0.991**	0.977
	Variation B	0.000 194	0.000 537	42.98	38.23	0.987	0.967
	Variation C	0.000 540	0.001 154	41.23	33.64	0.931	0.977

The best results are in bold and the suboptimal results are underlined

Conclusions

In this work, we propose a novel anti-JPEG compression binary data hiding method based on spatial channel fusion Transformer (SCFformer), aiming to provide a large-capacity and secure data hiding method to achieve high-precision secret information recovery with a low quality factor. The design of SCFformer can provide some inspiration for further research on hiding a large amount of binary data in JPEG images.

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