Binglong LI, Shilong YU, Yong ZHAO, Yifeng SUN, Chaowen CHANG, Qingxian WANG, 2026. Image fragment carving based on DCT semantics and an adjustment factor. *ENGINEERING Information Technology & Electronic Engineering*, 27(4):250140. https://doi.org/10.1631/ENG.ITEE.2025.0140

Image fragment carving based on DCT semantics and an adjustment factor

Key words: Discrete cosine transform; Fragmented image files; Memory media

Corresponding author: Binglong LI
E-mail: lbl2017@163.com
ORCID: https://orcid.org/0000-0003-3421-5432

Motivation

1. File fragmentation is a major obstacle in digital forensics, hindering evidence recovery.
2. Existing methods rely on pixel-level features (e.g., color difference), which are error-prone and rarely address memory forensics.
3. There is a lack of effective utilization of image semantic information for fragment reassembly.

Main idea

1. We propose a novel algorithm that uses discrete cosine transform (DCT) semantic features to measure the similarity between fragments and introduce a weight adjustment factor based on Joint Photographic Experts Group (JPEG) compression properties to validate matches.

2. This approach aims to significantly improve carving precision and reliability, especially for memory forensics.

Method

1. To achieve efficient lossy image compression with acceptable visual quality, a DCT-based JPEG encoding and decoding pipeline is adopted to eliminate spatial and visual redundancy in image data.

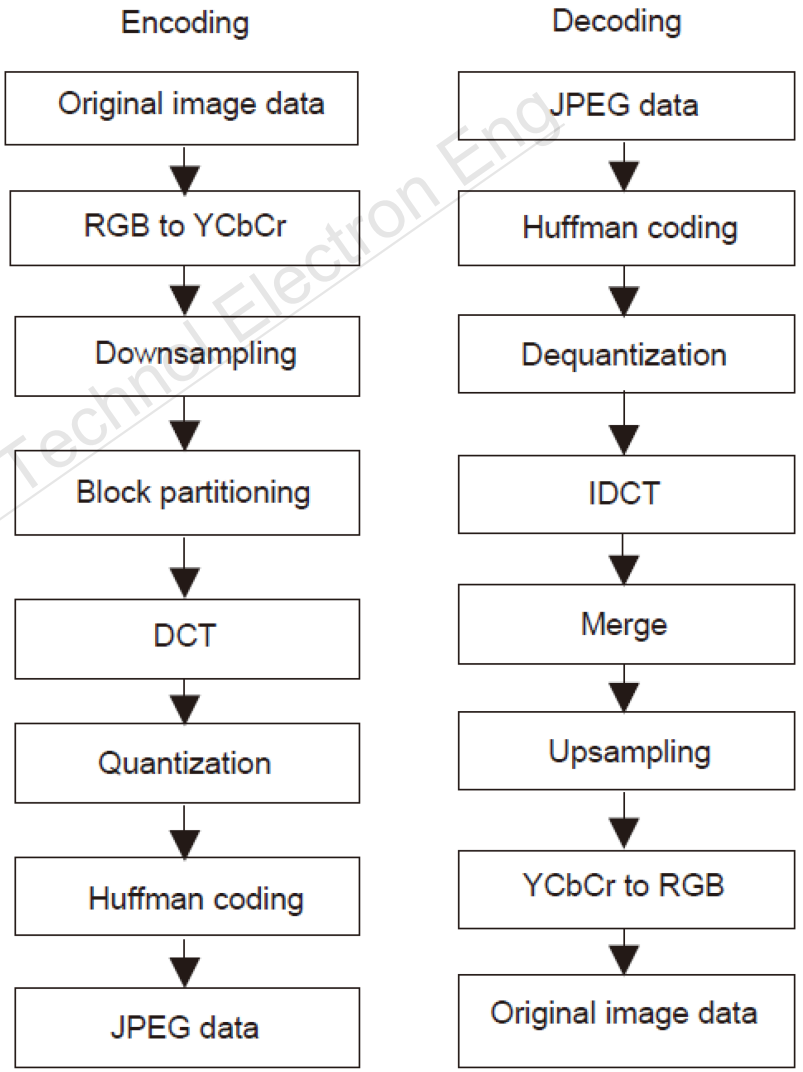

Fig. 1 JPEG encoding and decoding processes (DCT: discrete cosine transform; IDCT: inverse DCT)

Method (Cont'd)

2. To improve the compression efficiency of DCT-transformed image coefficients, a zigzag scanning order is adopted to rearrange the two-dimensional (2D) frequency matrix into a 1D sequence for subsequent entropy coding.

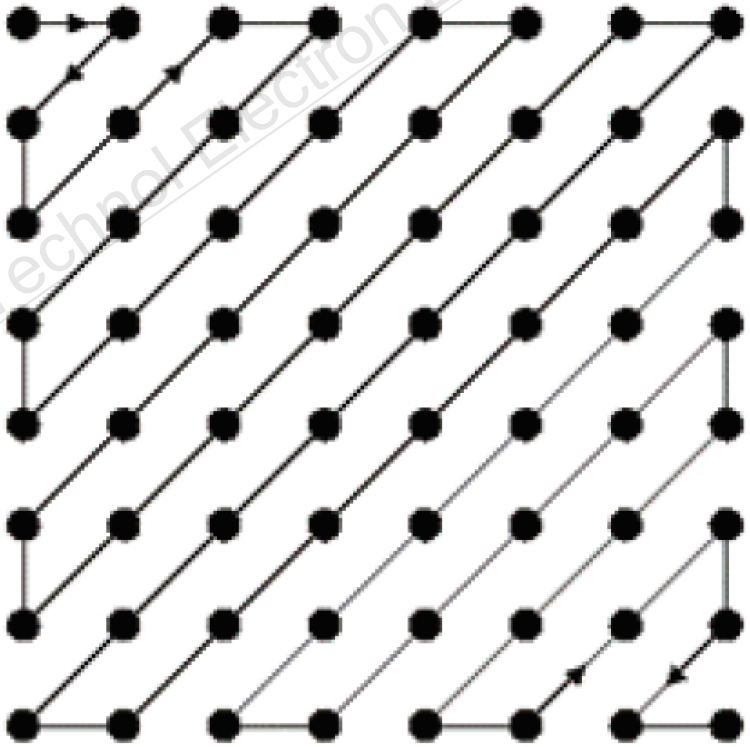

Fig. 2 Zigzag scanning order

Method (Cont'd)

3. To quantify the correlation and matching degree between data fragments, a connection similarity calculation model for fragments f_i and f_j is proposed to evaluate their structural and sequential alignment.

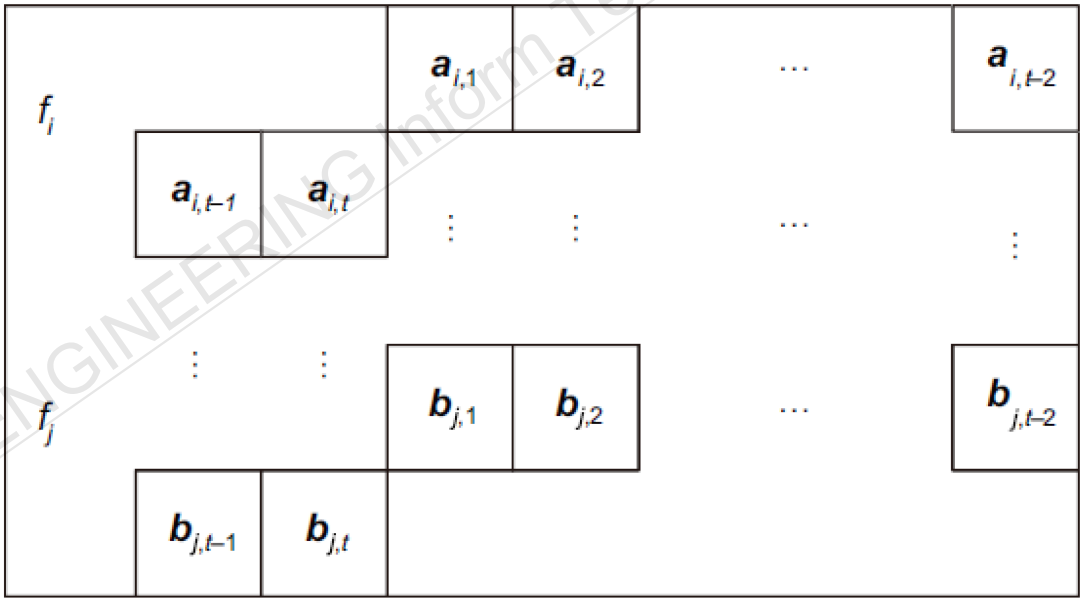

Fig. 3 Connection similarity between fragments f_i and f_j

Method (Cont'd)

4. To achieve accurate reconstruction and restoration of fragmented images in digital forensics scenarios, an image fragment carving algorithm framework based on DCT semantics and an adjustment factor is proposed. After constructing a fragment set through preprocessing, the header and body fragments are separated via the image file header fragment recognition algorithm, and separate linked lists are established. The fragment connection weighting algorithm is then applied to perform bidirectional carving and association matching of fragments, ultimately realizing the recovery of complete image files.

Method (Cont'd)

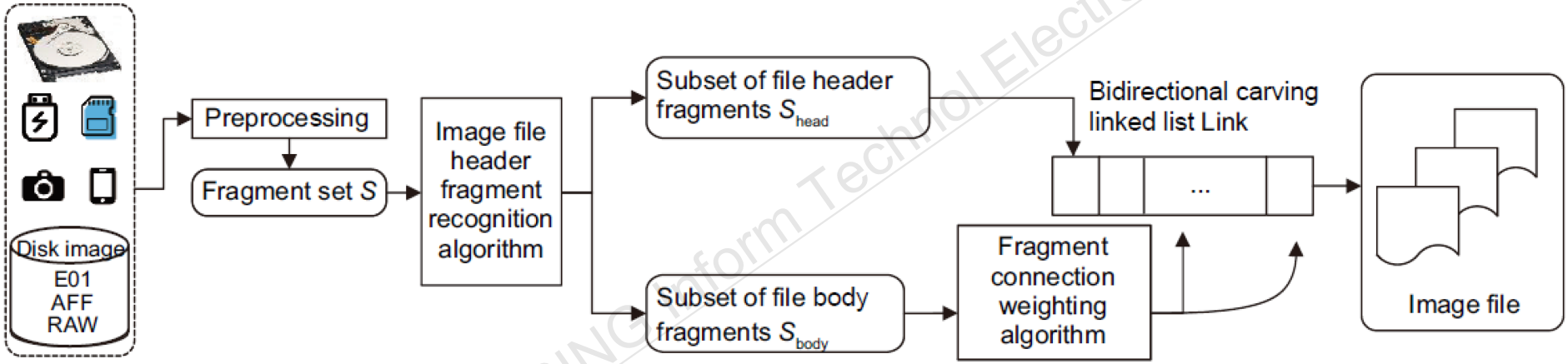

Fig. 4 Framework of the image fragment carving algorithm based on DCT semantics and an adjustment factor

Major results

Weight distribution results with/without the adjustment factor

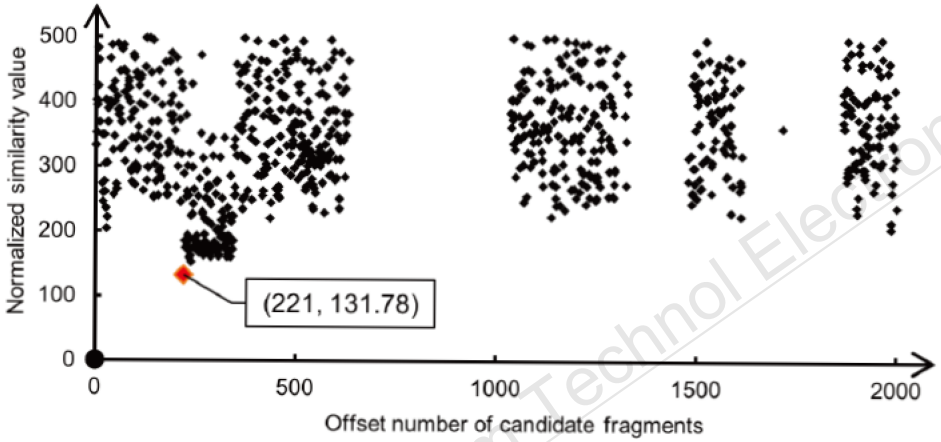

Fig. 5 Scatter plot of weight results between fragment 31 532 and the subsequent 2000 fragments (with the adjustment factor)

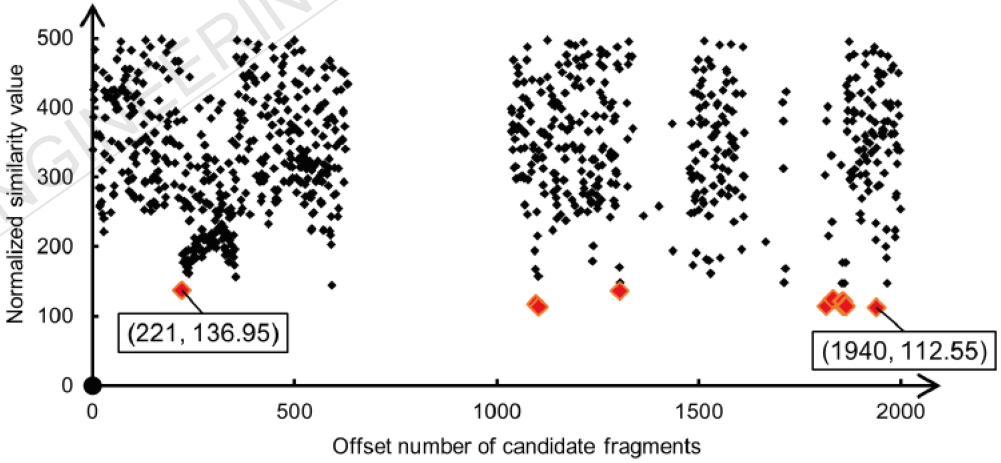

Fig. 6 Scatter plot of weight results between fragment 31 532 and the subsequent 2000 fragments (without the adjustment factor)

Major results (Cont'd)

Comprehensive performance evaluation of the proposed image fragment carving method

Table 1 Statistics of successfully carved files

Carving method	No. of carved files	Accuracy (%)
Scalpel	9	64.3
PhotoRec	10	71.4
APF	13	92.9
Our method	13	92.9

Table 2 Carving results for JPEG files in USB drive

Fragmentation type	No. of JPEG files	No. of carved files	
		Our method	APF
Contiguous file	189	189	189
2 fragments	110	107	90
3 fragments	106	101	65
4 fragments	84	76	36
5 fragments	40	30	11
6 fragments	10	6	1

Major results (Cont'd)

From memory traces to recovered images: carving results of the proposed algorithm

Fig. 7 Carving result generated by the proposed algorithm

```
FF D8 FF E0 00 10 4A 46  49 46 00 01 01 01 00 00
00 00 00 00 FF DB 00 43  00 05 03 04 04 04 03 05
04 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
```

Fig. 8 JPEG file traces in the memory image

Conclusions

1. This work presents a DCT semantics-based image fragment carving algorithm with an adjustment factor, achieving high-accuracy recovery of fragmented JPEG files in digital forensics.

2. The proposed method outperforms traditional carving tools, with state-of-the-art accuracy and superior robustness in highly fragmented scenarios.

3. It is validated to be effective for memory image forensics, enabling complete image recovery from volatile memory traces.

4. Future work will extend the method to more file types and optimize it for large-scale, real-time forensic applications.

Author Biography

Binglong LI (born in Weihui, Henan Province, China, in 1974) received his Ph.D. degree from Information Engineering University. He is currently an associate professor. His main research interests include digital forensic investigation, forensic education technology, disk forensics, memory forensics, smartphone forensics, cloud computing forensics, and network intrusion traceability.

Shilong YU (born in Weihai, Shandong Province, China, in 2000) is currently a master's student at Information Engineering University. His main research interests include information security, digital forensic investigation, disk forensics, and memory forensics.