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Research Article

Image fragment reconstruction and restoration method based on genetic algorithm

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ABSTRACT

How to efficiently and successfully stitch together fragments to reformat them into original images is an important and challenging problem in many disciplines, especially forensic science, archaeology, and investigative science. It is challenging for humans to perform this task as it requires much time, skill, and effort, and humans are prone to make mistakes. Therefore, automating the process through appropriate technology can significantly increase the problem-solving rate. The task can be accomplished faster and more efficiently, reducing the amount of work required to stitch the fragments together while increasing the efficiency of the entire process and significantly reducing human involvement. This study proposes an image restoration method based on reconstructing the edges of torn fragments. Torn fragments are often lost due to how they were initially torn, so an innovative model is proposed to replace the missing parts, i.e., using the Fourier inverse in combination with a genetic algorithm for edge replacement. For validation, 17 fragments of a particular image were input. The success rate of reconstruction was 86.6% for 15 of these images, 100% for 5 images, and 87.5% for the combined success rate, which proves the validity of the hypothesis of using the Fourier inverse to reconstruct the edges.

1. INTRODUCTION

In recent years, there has been some renewed interest in computer vision techniques aimed at automatically solving digitized jigsaw puzzles. This is mainly due to the fact that ostensible jigsaw "toy problems" can now be applied and successfully solved in a variety of interesting life reconstruction problems, e.g., in the fields of archival research, jurisprudence (broken bones, fractures), defense and investigative sciences, archaeology (reanalysis of mixed remnants or pottery fragments obtained from landfill excavations), artwork segmentation (reconstruction and fragmentation of historical paintings), and other fields.

Images may be torn up by hand or crushed by machines, and reconstructing torn or crushed images is a perplexing, complex, and arduous task that needs to be performed by a human operator, and often becomes intractable even with only a small number of fragments. In both cases, automatic reconstruction of the original image is a challenging process. In the case of machine shredding of the page, each fragment of the image has only straight edges, so the problem can be viewed as a jigsaw puzzle. But reconstructing the image manually is very different from the jigsaw puzzle problem mentioned. This is because the image produces uneven edges as it is torn, with tiny image fibers underneath the edges, which can produce unclear physical contours when compared to a jigsaw puzzle with smooth edges and well-defined corners. In fact, computers have been used in applications that classify pieces based on overall characteristics such as color, edge, and texture [1-3]. The method is reported to have a priori knowledge of the edges of the outer frame of the puzzle and is strictly limited to the shape of the puzzle pieces. It is assumed that standard puzzle pieces have four corner points and that the fragment boundary curve can be divided into four edges at the four corner points. However, in the case of image fragments, there is no restriction on the shape of the fragments and the corners are often difficult to recognize. The tearing process usually makes the fragment contour irregular and it is difficult to obtain a perfect curve match. In addition, image reconstruction has no a priori knowledge about the original content. In addition, due to the limitations of the imaging mechanism, scanned torn fragments may suffer from digital defects and unpredictable rigid transformations. In this case, the in homogeneity of the tear edges poses a serious problem for automatic image reconstruction [4-6].

The image fragments can be used to analyze the final reconstructed image. The time required to reconstruct the image depends on the size and number of fragments and can take days or weeks. Some fragments are sometimes missing for such tasks, so the image can only be partially reconstructed. Even then, the tedious and laborious manual work of rearranging the

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fragments can be alleviated. One of the problems faced when reconstructing an image manually lies in its manipulation. The physical reconstruction of an image modifies some aspects of the original image because products such as glue and tape are added to it. This type of manipulation is known as destructive analysis; most image processing methods involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it, and in many cases, local shape analysis produces fuzzy matches that get worse as the number of puzzle pieces increases. A global arch technique is needed to remove ambiguities in global images [7-10].

Edge-matching jigsaw puzzles are another popular puzzle, similar in spirit to jigsaw puzzles, that first appeared in the 1890s. In edge-matching puzzles, the goal is to arrange a given number of tiles (usually squares) of the same shape but different patterns to match the edges of neighboring tiles. Typical patterns range from salamanders to frogs to insects. However, in its simplest form, each edge of a tile is painted in one of several colors, and adjacent tiles must be painted the same color along their standard edge [11].

Edge detection is a term used in image processing and computer vision, especially in the field of feature detection and feature extraction, to refer to algorithms aimed at identifying points in a digital image where the brightness of the image varies drastically or, more formally, has discontinuities. Boundary matching is one of the critical steps in the reconstruction of fragmented images, and an external boundary matching method based on corner points is proposed for finding the exact connection between two fragments since each fragment is considered unique and can be used as the main parameter for finding connections between multiple fragments. In each shard, the corner points are the farthest points from its center of mass point, and they are always familiar to many different shards, along with the boundaries that can be matched using multi-scale shape race boundary matching to obtain the final exact match.

Since the two fragments are oriented correctly, only one matching corner point needs to be determined to match all corresponding points of the two fragments. [12]. GA will deal with the Fourier/GA problem in signal reconstruction, where GA searches in the solution space, where non-analytic methods are used to derive the orientation of the two fragments, and only one matching corner point needs to be identified to match all the corresponding points Fourier series coefficients are used in the problem Genetic Algorithms, Non-Analytic Algorithms, which are often need to be used, these algorithms lose parts of the complex image and need to be re-formed [13].

Image correlation is widely used in image and picture processing when connecting image segments; correlation algorithms are a better way to solve this problem. This process, also known as template matching, is used to locate objects in an image or to connect segments of two images in image alignment. It is used in some forms of detection to find step edges between two regions or to find lines, points, and curves [14]; Fig. 1 shows a full or partial reconstruction of an image.

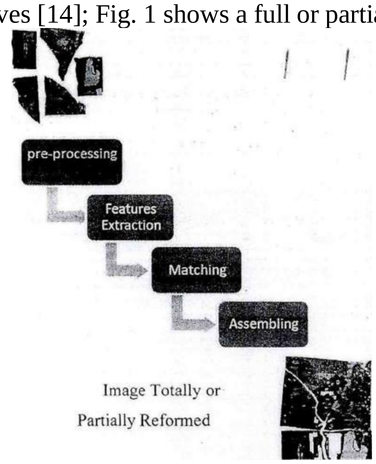

Fig. 1. Total or Partial Reconstructed Image

Images produce uneven edges when torn, resulting in the desired shear containing tiny paper fibers, which can lead to ill-defined physical contours. In addition, due to the limitations of the imaging mechanism, torn fragments may contain digital defects and unpredictable rigidity transformations after being scanned. Therefore, some non-ideal conditions should be considered during the reconstruction process. Therefore, the following provisions can be incorporated.

1. Manually shredded paper may have an arbitrary shape and many edges; this depends on how often the corresponding image has been shredded. However, each torn fragment should contain several abrupt discontinuities (corners) in the overall contour direction.
2. A given torn fragment may or may not contain straight edges (i.e., raw machined edges). In addition, there may not even be a single piece with a straight edge for a given collection of torn pieces.

3. Some shearing may occur when tearing off a sheet of paper. Shearing will occur due to twisting and tilting of the grip, and the resulting tear will be along the surface and thickness of the paper. As a result, the torn paper will overlap partially along its matching edges.
4. We have no a priori knowledge of the contents of the document.
5. The corners of a torn paper may be topologically different from the corners of its corresponding paper, depending on the nature of the hand motion and the behavior of the corner detection process.
6. There may be slight gaps between correctly matched paper images.
7. Scanned images of torn paper will undergo unpredictable rigid transformations (translations and rotations) during image acquisition.

h. Since there is no a priori information, the corresponding scanned image can be either of its two surfaces for each torn paper.

Thus, the problem of computer-aided reorganization of torn paper is similar to that of a jigsaw puzzle but also poses other challenges.

Many methods have been developed to reassemble fragments to recombine 2D images and 3D objects. For 21) images, the only information available from these methods is obtained from the fragments when the final integration result is unknown. More importantly, two fragments torn apart by hand do not necessarily have the same edges. The paper has the awkward property that torn edges may have inner and outer boundaries. Justin proposed a polygonal approximation method to simplify the complexity of the fragments. Several features are extracted from each fragment, such as the angle between edges and the distance between vertices. The next step is to compute the similarity between fragments and then perform a global search.

Wolfson, 1990 "On Curve Matching" describes two curve matching algorithms where the boundaries are represented by strings of shape features obtained by polygon approximation. The matching phase finds the longest common substring and solves it by geometric hashing. The algorithms described by Wolfsón are high-speed and are therefore used by most puzzle-solving methods. According to Kong and Kimia, these algorithms fail when the number of puzzle pieces becomes large. However, their expensive computational cost undermines their use in puzzle-solving [15].

H. Bunke, U. Buehler, 1993 [16] Approximate string matching in shape recognition. Moreover, H. Bunke, G. -8 "Solving jigsaw puzzles using approximate string matching and best-first search," Dynamic programming has been used to solve jigsaw puzzles.

W. Kong, B. Kimia, 2001 [17] "On solving 2D and 3D jigsaw puzzles under curve matching" suggests using polygonal approximation to resample the boundary to reduce the complexity of curve matching. They used dynamic programming to align a reduced version of the boundary. They again applied dynamic programming to the original boundary to obtain fine-scale alignment. A similar approach was applied. H.C.G. Leitao, J. A multiscale method for reassembling two-dimensional fragmented objects. They used an incremental dynamic programming sequence matching algorithm to compare the curvature of the fragments at progressively increasing resolution scales.

B. Biswas, P. Bhowmick and B. B. Bhattacharya, 2005 [18] "Reconstruction of Torn Documents Using Contour Maps" In order to be reconstructed, torn pieces of paper have to be assembled in order to form an image of the whole page of a paper document.

L. Zhu, Z. Zhou, and D. Hu, 2008 [19] "Global Consistent Reconstruction of Torn Documents," Shape features, i.e., rotation functions, is the work carried out in this regard, the above uses a shape representation of the paper sheet in order to estimate the reconstruction of the original document from each broken contour. It is used to discover matching contour segments. After that, a confidence score is assigned to each match.

2. METHOD

Digital image processing starts with an image and generates a modified version of that image; Wechsler's dictionary defines a number as; "a computation by numerical methods or in discrete units" and defines a digital image as; "a numerical representation of an object" defines processing as "the act of processing something" and defines process as; "a series of actions or operations that lead to a desired result [20].

An image is a matrix whose row and column indices determine the location of points; the corresponding elements are called image element pixels. Images are two-dimensional, e.g., photographs and screen displays. They can be captured by optical devices (e.g., cameras, mirrors, telescopes, microscopes, etc.) and by natural objects or phenomena (e.g., people or water). Image processing is a form of signal processing in which the input is an image, e.g., a photograph or a video frame; the output of this processing may be an image or a set of features or parameters associated with the image. Image fragmentation is re-forming or stitching a continuous image from a set of separate or overlapping images [21].

The various methods used for image fragmentation can be broadly categorized into direct and feature-based methods. Direct methods are helpful for fragments with large overlapping regions, small translations, and rotations. Feature-based methods can usually handle small overlapping regions and are usually more accurate but computationally intensive; images are bonded physical or digital representations with communication capabilities; fragmentation is one of the methods for automatic reconstruction of fragmented images to find globally consistent solutions from fuzzy candidate matches, the candidate disambiguation problem is formulated in a relaxation scheme, where a definition of compatibility between neighboring matches is proposed, and the global consistency is defined as a global criterion [22].

2.1 Pre-processing Stage

The purpose of the preprocessing stage is to estimate the contours of the fragments. In the application of traditional algorithms, each piece of the image is preprocessed by polygon approximation to reduce the complexity of the boundaries. Then, a set of features is extracted from each polygon. Preprocessing does not increase the information content of the image, but is useful in cases where it helps to suppress information related to a specific image processing or analysis task (i.e., background subtraction), and the purpose of preprocessing is to improve the image data so that it suppresses unwanted distortions and/or enhances the image features relevant to fill processing [23-24].
The filtering stage takes the observed contours as input and outputs the smoothed contours. Filtering serves two different purposes: firstly, it is used to remove from the contour insignificant irregularities that are caused by artifacts from the image acquisition and contour extraction process or erosion of the material behind the debris. For this purpose, it is necessary to remove the high-frequency components of the contour, since they are the frequency components most affected by these perturbations. Secondly, filtering is used to reduce the complexity of the contours in order to speed up the recognition of similar contour segments [25]. Fig. (2.4) shows the median filter for calculating the median value of a pixel neighborhood.

123	125		130	140
122	124	126	127	135
	120	150	125	134
			123	133
	126	110	120	130

Fig. 2. Median Filter

When calculating the median value of a pixel's neighborhood, as shown in Fig. 2, the central pixel value 150 is not representative of the surrounding pixels, so the median values 124, 127 are used instead. The main principle of the median filter is to filter the signal entry by entry, replacing each entry with the median of the neighboring entries. The pattern of neighboring entries is called a "window" [26].
Feature extraction (or detection) aims to localize significant feature regions on an image based on its intrinsic properties and applications. These regions can be defined as global or local neighborhoods and are distinguished by shape, texture, size, intensity, statistical properties, etc. Local feature extraction methods are categorized into intensity-based and structure-based methods. Intensity based methods find regions that satisfy the desired uniqueness or stability by analyzing the local intensity [27]. Structure based methods detect image structures such as edges, lines, circles, ellipses etc. Feature extraction tends to identify features that form a good representation of an object in order to differentiate across object classes with tolerance for variation [28]. Feature detection is a low-level image processing operation.
That is, it acts as the first operation performed on an image and checks each pixel for the presence of features. If this is part of a larger algorithm, then the algorithm will typically check only for age in the feature region as a built-in prerequisite for feature detection [29]. When detection is computationally expensive and there are time constraints, a higher level algorithm can be used to guide the feature detection phase in order to search certain parts of the image for features. Many computer algorithms use feature detection as an initial step and, as a result, a number of feature detectors have been developed that vary widely in terms of the types of features detected, computational complexity, and repeatability [30].
Extracting the orientation of all torn pieces and extracting their edges is a process that needs to be performed during the identification of the matched pieces as the first selected piece (which can be referred to as the first iteration). Individual geometric parameters of all torn pieces are extracted during this initial process and these parameters can be used to identify matched pieces as remaining pieces [31].

2.2 Reconstructing Incomplete Signals

First part: the feature part - this part characterizes the signal or edge, in other words, this represents the characteristics of each edge to be matched.
Second part: the complementary part, this part can be revealed from the features. In any case, a single part of the edge can be represented as a signal by the following equation.

$$f(n) = fv(n) + fM(n) \qquad (1)$$

Where: fv (n) is the visible edge portion and fM(n) is the feature polynomial and continuous function whose features are not shown directly from the genetic algorithm but are recognized flags from the genetic algorithm.
In image restructuring, the edges of individual fragments are characteristic polynomial and continuous functions; this proposal is expressed as the following features:

$$F(x) = 9 + Ean * cos(nx) \qquad (2)$$

It is best to use this decomposition

1. the function F(x) can be integrated infinitely, and
2. Uniform convergence ensures point-by-point convergence
3. Spectral information is preserved.

The proposed edge and the signal are using edge i3 as shown in Equation (3).

$$cos(nx) + bn * sin(nx) \qquad (3)$$

The original signal is converted to frequency and the complete signal is obtained by finding the proper F (x) i.e., the exact transformation F (x) of f(n), thus accomplishing the desired task.
The Fourier series transforms the surface topographic vector into a meaningful function F (x). Assuming that its Fourier series (and equal) hold, as shown in the equation:

$$bn * sin(nx) \qquad (4)$$

The reason is as follows: represented as a linear combination of infinitely differentiable functions. Meaningless, discontinuous or approximate ones will be ignored. The derivative FO(x) can be expressed in terms of the same coefficients as in equation (5).

$$\frac{d}{dx}\{f(x)\} = \sum_{n=1}^{+\infty} \mathrm{n}(\mathrm{bn}\cos(\mathrm{nx}) + \mathrm{an}\sin(\mathrm{nx})) \qquad (5)$$

The reconstruction problem now reduces to finding the coefficients an and bn - coefficients of g F{x} or FIX} are the same. Each point x, -ax dx {F (x)} is expressed as a sum of I -FIN terms. Therefore, all N points on {F (x)) can be represented by N (I + N) terms.
Step I: Select a set of Fourier coefficients.
Step 2: Using these coefficients, perform a ctan approximation using either the constraint method or the standard search method and compare it to the supplied signal by calculating (squared error).
Step 3: Based on the squared error, select another set of Fourier coefficients from the search space and go to step 2 [6].
Genetic algorithms are a powerful and widely applicable stochastic search and optimisation technique. Perhaps the most widely known type of evolutionary computational method today, in general, genetic algorithms have five basic components, as summarize by Michaelmas.
A number of commonly used optimisation techniques are reviewed to determine their utility for broken images Knowledge-based techniques (production rule systems, heuristics): the rules of these systems have a limited range of applicability, tend to be fragile, and are often difficult to formulate. In addition, the visual knowledge required by these systems may not be re presentable in a knowledge-based format.

The complex challenge with this approach is the use of a genetic algorithm to find the Fourier transform of a given edge; when the edge can be represented as a polynomial, a population must be generated in order to initiate a genetic session. The real challenge is the size of the problem domain (i.e., the search space for optimisation), as shown in Equation (6).

$$F\ (e) = ao + at\ sin\ wt + bi\ cos\ wt \qquad (4)$$

The search space would then be (2128.sizeof(point), which is a very large search space even though point is represented by only I bits, which is how the proposal manipulates the edge points, and the time taken to find the optimised Fourier coefficients would be multiplied by the number of windows that make up the edge if a large size fragment is chosen.
Genetic representation of the problem solution

1. a method for creating an initial population of solutions.
2. evaluation function to rate the solutions based on their fitness.
3. the genetic operator changes the genetic composition of the children during reproduction.
4. values of genetic algorithm parameters.

3. PREPARE YOUR PAPER BEFORE STYLING

A practical example of step-by-step processing was used to demonstrate the sequential procedure required to complete the reconstruction of a fragmented image. As described in the previous chapter, a genetic algorithm is used to interpolate the edges of the extracted fragments by estimating the coefficients of the Fourier equation representing the edges in the frequency domain; since its processing phase produces huge and difficult to interpret values, the pd in this chapter provides a simple example in order to provide a deeper understanding of the key role that the genetic algorithm plays in the proposed system.
Figure (3) shows the main GUI that pops up when the system is called for the first time; the GUI consists of four main areas, namely the workspace, the alpha mask, the output window and the next fragment.

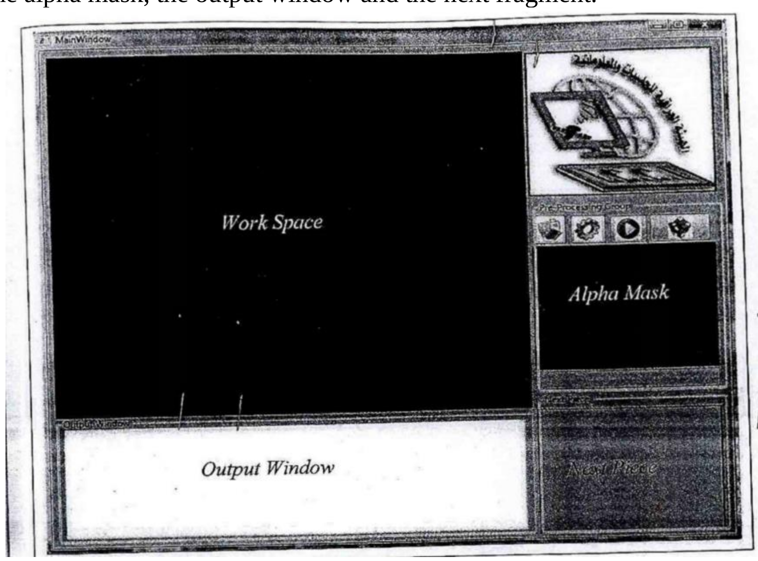

Fig. 3. Main Window of the Proposed Implementation

The workspace is the area where the broken image is saved before the reconstruction process, where the fragments are added to the canvas and processed into polygonal shapes, later the canvas will be rendered as a bitmap image that needs to be reprocessed to extract its objects again, it is used to merge two pieces of the broken image and process them into one piece later as shown in the figure below [32]. The alpha mask window is used to display the alpha masks that have been prepared for the images shown in the workspace window. The Alpha Mask window is used to display the alpha mask prepared for the image displayed in the Workspace window. The Output window is used to inform the user about the current state of the system at each stage of the process. The Next Piece window is used to display the next piece selected from the 0b' Cts' list, which is used to test whether the next piece matches the current object displayed in the Workspace window [33].
The next step is to alpha mask the entire image by applying a median filter, which is a nonlinear digital filter used to remove noise from an image. This is a typical preprocessing step used before further processing of the image, especially edge detection, as the nature of this filter is to remove noise while preserving edges [34].

Figure (4) shows the effect of applying an alpha mask to a selected image; the alphamask window holds the resulting alpha mask image fragment. alpha masks are used to analyse an image into two layers, an object layer and a background layer; this allows for a more accurate realisation of the object. The process of creating the alpha channel has a different quality due to the different contrast between the object and the background. In this realisation the background has been set to white.

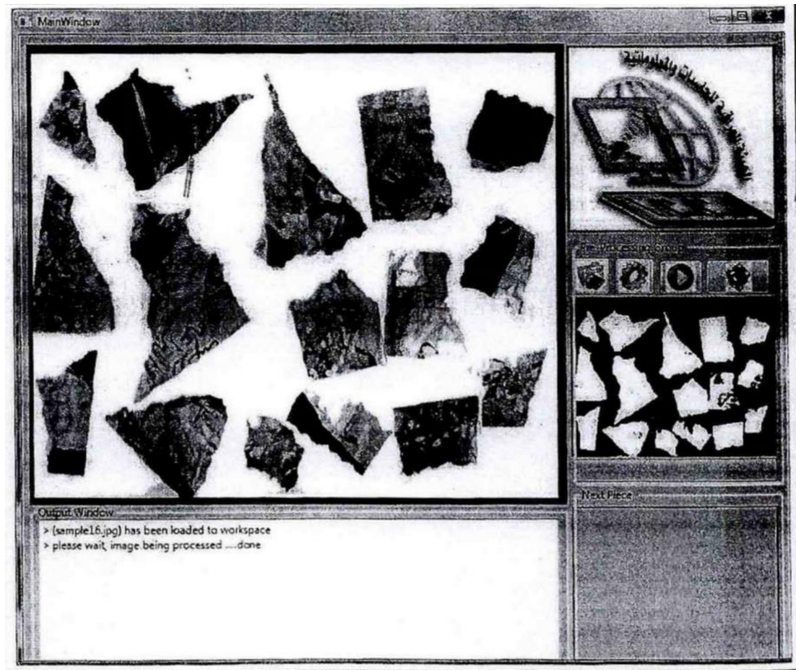

Fig. 4. Alpha Filter Applied to Get Image Mask

After the image alpha masking, the object extraction can be done by representing the Blob Counter object from the AForgenet C# library, which has a number of APIs for extracting blobs from the original image, and after the processing is complete, a list of blobs will be maintained in the object list.

There are many challenges in implementing the system proposed in torn image reconstruction b, including:

1. fragments of torn images have composite edges due to the nature and characteristics of the paper structure. Composite edges sometimes consist of four to eight layers. This problem introduces new challenges in the pre-processing stage of the presented proposal, where matching is highly correlated with the shape of the edges. The proposal suggests a matching scheme for reassembling the image using cross-correlations that depend only on matching edges; this requires working on the same layer of the torn paper.
2. The preprocessing phase begins with the generation of an alpha mask for the torn image; this mask is later used to extract objects representing the torn fragments. Generating an effective alpha mask was a real challenge in this study due to the low contrast between the drum piece and the background; this introduces a variable distortion rate at the edges of the missing part of the extracted object. The missing part is a major issue in the matching scheme proposed in this thesis.
3. In this thesis, the edges are treated as signals and the assumption is that the inverse Fourier transform is applied to regenerate the missing parts of the edges. This assumption has a number of constraints as shown in Equation 1, where

where: the edge, P(e) is the polynomial representing the edge and FT(e) is the Fourier transform of that edge.

4. CONCLUSION

Torn image reconstruction cannot be accomplished by considering only the edges due to the distortion produced by the preprocessing tools. Reconstruction of torn fragment edges using image filters introduces torn fragment edges that are different from the original edges. As the construction of the partially assembled image progresses, the complexity of matching fragments increases. This is due to the matching error rate that occurs when assembling the image, as larger assembled images introduce larger edges (i.e., perimeters), which can consume more time to process larger objects such as rotations or translations. The Fourier inverse can only reproduce edges that are isomorphic to the signal generated by a periodic source and will not produce good results for custom or random edges. Edge reconstruction is the most effective factor in the process of reassembling a torn image, due to the nature of the tearing process, in which a torn fragment contains many fragments along its edges. Robbing on edges has both advantages and disadvantages, if its corresponding hole is present on the matching torn block, robbing can be used to complete an effective matching process, on the other hand, if robbing is present on one fragment and no hole is present on the other or vice versa, the matching will be destroyed.

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Conflicts of Interest:

The authors declare that they have no conflicts of interest in relation to this work.

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