Review Paper on Stitching of Torn Documents

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Abstract - Document mosaicing is the process of combining or joining various document fragments based on certain matching characteristics. The process of efficient stitching of document pieces is a challenging and resource-intensive process, which has applications in forensics, archaeology and legal documentation. A major problem in document mosaicing is figuring out a fast and efficient way to join document pieces without compromising on the quality of the input image. This paper aims to compare and review the various techniques that have been proposed to solve the problem of stitching documents.

Index Terms - Image Stitching, Document Reconstruction, Image Processing.
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I. INTRODUCTION

Solving the Jigsaw puzzle is one of the finest entertainment for children in their kindergarten schooling [9] [10]. Solving puzzles has always helped in analogical development of human brain in their early ages. This time consuming process of solving the puzzle involves tedious mental tasks of considering zig-zag edges, color differences, imagination of final image, text matching in the images and trial and error methods. While the idea of puzzle solving can be very useful in domains such as forensics, archaeology, legal documents etc., solving the torn documents manually can become inefficient as results are required in very limited time. In the field of forensics, reconstruction of shredded document plays a vital role. Shredded pieces of documents can be huge in numbers and stitching them manually and logically is an impossible task. Considering the gravity of these problems it has become paramount to develop a system that can automate the process of image and document stitching. Not only does physical reconstruction involve manual manipulation for solving the puzzle but also it involves the modification of the document as it is joined using adhesive and tapes which can destroy the originality of the document, known as destructive analysis. Automatic software based solution to torn document is a major requirement in the field of document reconstruction. The techniques of extraction of boundary, text extraction and mainly the orientation of the document are undergone by many researchers [11] [12] [13]. This paper focuses on the review of various techniques of image stitching and document reconstruction which are either ripped up by hand or are torn because of external reasons such as shredded documents and notebooks. It shows the general tools and methods for semi-automatic and automatic reconstruction of documents. The rest of the organization of this paper is as follows. Section II describes the general framework, Section III focuses on various image stitching techniques for various types of torn documents. Furthermore, Section IV concludes the paper.

II. DOCUMENT IMAGE RECONSTRUCTION FRAMEWORK

A general framework for reconstructing documents based on fragments and features is discussed below. The block diagram of the framework is shown in Fig. 1. The reconstruction process is as follows:

1. Ripped up fragments of the document are collected and arranged for easy indexing.
2. Image preprocessing techniques such as gray scaling, contour extraction and polygonal approximation are used to reduce the complexity of the fragments
3. Feature extraction is used to extract relevant features in the document, which can be used to merge different fragments. These features for each fragment include physical features such as edge length, vertex angle and orientation of the text as well as inherent features of the document which are characteristic to a particular document, such as the characters printed on the document and the color of the ink or paper.
4. Based on the extracted features, an optimal algorithm is identified and document mosaicing is done.
5. Global Reconstruction is used to ensure that consistency and completeness of the reconstructed document is maintained.
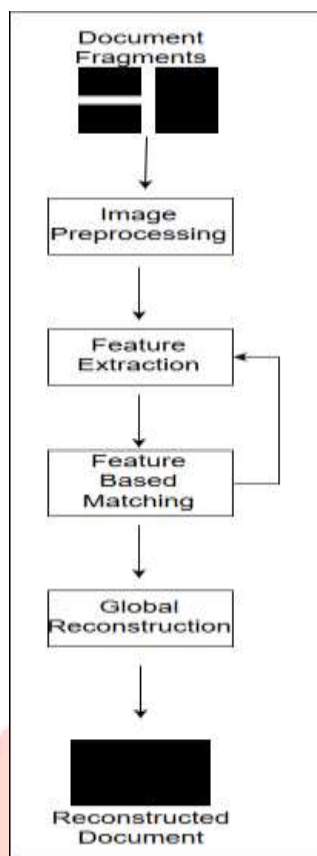6. Finally, a complete reconstructed document is obtained.

Figure 1: Basic Framework for Torn Document Reconstruction

III. DOCUMENT STITCHING TECHNIQUES FOR TORN DOCUMENT

In [1], Matthias Prandstetter and Gunther R. Raidl have presented a solution for shredded document reconstruction which can bring paradigm shift in the fields of forensics and investigative sciences. Shredded paper documents are usually horizontal or vertical stripes of same heights. They can also be small geometric shapes like rectangles and hexagons. The two step solution mentioned for the reconstruction is firstly, acquiring the strips and scanning them using a scanner. Further in this step feature pattern recognition and image processing tasks are applied to identify bounding boxes and orientation of the strips, text color, paper color and other useful features. In second step, features derived are used for clustering the strips which can be potentially belonging to a same original document. This system is motivated by two major drawbacks in reconstruction of shredded documents: There is no information of how pieces or strips are to be appended to form original page(s) and clustering approach can only reduce the problem size and not provide a final solution. For these drawbacks the proposed approach is *reconstruction of strip shredded text documents* (RSSTD).

RSSTD has first applied the clustering algorithms thereafter reformulating it as *traveling salesman problem* (TSP). Assumption such as height of strips to be same is taken and if not clustering is applied on the strips to segregate them with respect to their heights. Further, all complete blank strips are eliminated reducing the search space. The proposed solution for RSSTD are as follows:

1. Reformulation as a TSP: Size of original instances of RSSTD can be large and hence applying algorithms cannot be applied on real world problems. Thus, it uses Chained Lin-Kernighan Heuristic for reformulating the RSSTD as a TSP.

2. VNS and Human Interactions: Humans experiences and intuition are very reliable when considering the related text blocks and documents contents. Human knowledge along with the Variable Neighborhood Search (VNS) provides efficient solution for RSSTD.

This approach has proved that neither humans nor heuristic approaches are able to produce the results, but a hybrid system performs very well with integration of various automated optimization techniques.

In [2], Ant colony optimization works on the mechanism of ants following their colony by the amount of traces of pheromone that the ant members have left while walking along the paths. In this method for reconstruction of cross cut shredded text documents, two pheromone matrices indicating the amount of pheromone laid for placing shred j just next to shred i and for placing shred j on top of shred i, are used. These matrices are then used with three construction heuristics namely: - Randomized Greedy Matching Heuristic (RGMH), Randomized Row Building Heuristic (RRBH) and Randomized Prim Based Heuristic (RPBH). A cost function c(i,j) is used to indicate the extent of error generated when shred i and j are stuck together. This cost function needs to be minimized.

1. RGMH is used to find the best match between two shredded pieces iteratively till a single sequence of such pieces is formed. This long, single sequence is then split into multiple rows. The match between any two pieces is fixed for obtaining the best match using a probabilistic function comprising the initial value of pheromone matrix and the cost function c(i,j).

2. RRBH uses a slightly modified probabilistic function compared to RGMH, using cost function c(i,j) and the initial value of pheromone matrix to directly form proper rows from the shredded pieces.

3. RPBH also uses a function to place a shred piece i on the top, bottom or to the sides of a shred piece p. This is done iteratively to match each shred piece to its neighbor to reconstruct the cross cut shredded document

In [3], a method is developed for puzzle assembly which contains surface texture in the torn pieces. It proposes a two stage approach for the image reconstruction. As the system needs texture based torn pieces, it tries to maximize the texture matching and continuity of the texture on the torn pieces. For achieving this, firstly the pixel values of pixels around the boundary of every pieces are calculated separately. Later using inpainting and texture synthesis, the boundaries of every piece are extended as the matching of extended boundaries will have greater matching by correlating it with the neighboring region. Secondly, features from image such as variance and pixel intensity values are calculated. Using Euclidian distance to for all features and texture during the matching a cost function is calculated while joining the pieces. The more negative the cost function, more the accuracy of the system. This approach is costly because of the distance calculation for all pieces thus the FFT shift is introduced.

FFT shift uses the most correlated pieces, which then expands them and feature extraction is carried on. The mean of these features is calculated and constraint expression is applied. The maxima in is found in the matrix of both the pieces and these maxima are used for the translation and joining of the two pieces. The cost function is then calculated for these joined pieces. This process is carried out iteratively till the complete image is formed.

In [4], the reconstruction of shredded notebook paper is done. The notable features of notebook papers are the color, pulp used and the size which all remain constant for a given notebook. The font of writing and for hand written documents the handwriting of the writer will remain same. For reconstruction with such constraints squared paper method is used. For detection of such geometrical form Hough transform is used. Thus, with the use of square paper blocks the shredded notebook is stitched by linking the similar features of font, handwriting and color of the remnants. This gives a semiautomatic method for reconstruction of document which is limited to only notebook size papers with specific thickness.

In [5], a software based solution to the problem of image stitching is proposed. In this, document text and characters are extracted and fragments are separately joined. Text reconstruction is done based on the structure of the reconstructed document. First, orientation of images is identified based on the orientation of text. Then, boundary detection and corner detection is carried out using pick distance method. For the process of corner matching, two techniques are used- Half-Quadrant Matching and Adjacent Corner Angle Matching. For final corner matching, the process of Shape Based Boundary Matching technique [15] is used with various levels to test the technique's correctness. Then, the process of maskblending is used to blend the boundary of the extracted text image. The final step includes combining the fragments using Shift and Merge method. In this, the host fragment is kept at the center of the image and guest fragments are attached keeping in mind the coordinates of the guest image. The output produced is clean and efficient because of the accuracy of text extraction and corner matching.

In [6], a three-step approach for document reconstruction was used. This paper focused on merging fragments based on the physical features of the document fragments. The first step in the proposed methodology includes performing image preprocessing techniques using traditional puzzle-solving methods. In this, a specific problem is tackled, which is the creation of dual boundaries which can hamper the efficiency of matching. The inner and outer boundaries arise due to improper tearing of documents. This problem is solved using Douglas-Peucker algorithm. The Douglas-Peucker algorithm is a polyline approximation algorithm which is used to reduce dimensionality of the fragments. Image preprocessing is followed by feature extraction. For every fragment, the following five features are extracted:

- Angle of each vertex
- Euclidean distance from previous vertex
- Euclidean distance to next vertex
- X-coordinate of each vertex
- Y-coordinate of each vertex

The final step of the methodology includes computing similarity between polygons using a matching score. The fragment with the highest matching score is chosen as a match. Finally, the entire document is reconstructed by repeatedly using the method proposed by Leitao and Stolfi [14] for fragment matching. This method works for a small number of fragments, but as the number of pieces' increase, the performance decreases.

Guoqiang Liu, Jiehua Chen and Yayu Zheng proposed a novel idea for document stitching [7]. This is done in two parts: First, an overlapping region is identified based on the source images after which document stitching is done based on an optimal seam. The detection of overlapping region was done by running the input images in a pipeline of feature extraction and detection methods. First, edge detection is done followed by skew correction using Hough transformation to detect the orientation of the text. Then feature extraction is done using SURF feature detector, which helps in identifying key features of the printed text. Overlapping regions are identified through pixel matching.

The second part of this implementation method involves detection of an optimal seam in the overlapping area. This is done by first performing image thresholding based on clustering methods for binary images using OTSU Algorithm. Then, connected components are identified in the text using 4-connectivity or 8-connectivity. After getting the components, the text font is standardized so that it is easier for us to implement the stitching process. Once de-skewed image is obtained, the entire image is divided into rows, columns and individual characters. Horizontal and vertical projection is used to separate the background from the foreground. Finally, optimum feasible paths are identified based on the minimum calculated seam obtained using the horizontal and vertical projection techniques. Since this optimal seam is present in the overlapping part of both images, it is easy for us to find and overlap the seam in individual images. This ensures accurate stitching of images based on overlapping parts.

In [8], the authors propose an iterative probabilistic model for reconstruction of hand torn documents. The advantage of using a probabilistic model is that it gives a set of likely arrangements instead of one single fragment. The probability of intermediate and final arrangements of fragments is calculated by multiplying the individual probabilities of all edges involved. In this method, a seed fragment is selected from the set of fragments (n) to reduce computational complexity. Each fragment (n-1) is attached to the seed and a probability value is generated for each attachment. This newly attached arrangement is considered to be the new seed fragment and further the reduced set of (n-2) fragments is attached to the new seed, thereby generating another sequence of probabilities. Thus, the whole document is matched based on a tree of probability values generated, and the path with the maximum probability is chosen as the ideal combination. The probabilistic score is generated using a distance matrix whose elements contain the horizontal distance between the two fragment edges. This method gave an average accuracy of around 80%.

Table 1: A Survey on Document/Image Reconstruction

Application Area	Publication/ year	Title	Central Idea	Purpose
Shredded Document Reconstruction	Springer/ 2018	Combining to reconstruct strip shredded text documents [1]	Reformulation of the shredded strip reconstruction problem into the TSP and solve further by human interaction and VNS for joining the pieces.	To find solution for reconstruction of shredded documents.
Cross cut shredded Documents	ACM/2009	Meta-heuristics for reconstructing cross cut shredded Text Documents [2]	Reconstruction of a cross cut shredded text document with the help of construction heuristics incorporated within ACO and VNS models and their comparison.	To compare models for reconstruction of cross cut shredded text documents.
Automatic Puzzle Assembly	IPCR/2006	A Texture Based Matching Approach for Automated Assembly of Puzzles [3]	Solving the puzzle using surface texture and features of the image by expanding the boundaries and iterative matching of pieces giving the most negative cost function as the accurate result.	To automate the Puzzle solving with implications on image reconstruction techniques.
Shredded document Reconstruction	IEEE/2005	Features for the reconstruction of shredded notebook paper [4]	It proposes the method of reconstructing shredded notebook by matching constant features related to a notebook such as size, color, shape, material used and also considered the handwriting on the paper. It used square paper method.	Shredded notebook reconstruction with square paper method.
Hand torn document reconstruction	International Journal of Computer Applications/2011	Text Reconstruction using Torn Document Mosaicing [5]	The process of document matching is done in discrete steps: first, text is extracted and matched for all fragments. Then fragment matching is done based on the properties of the fragments such as corner points and edges. Finally, text is displayed according to the order of the merged documents.	To combine various text based document fragments using novel approaches.
Shredded document Reconstruction	IEEE/2005	Document Reconstruction Based on	Matching fragments of a document based on the fragment characteristics like length and	To automate the process of fragment

		Feature Matching [6]	angle after performing dimensionality reduction using polygon approximation.	matching keeping in mind the abnormalities that arise while tearing, such as double-edge formation.
Combining two pieces of a document when there is some kind of overlap involved	IEEE/2016	A Document Stitching Method Based On Optimal Seam [7]	The overlapping region is detected and an optimal seam is generated based on the method of connected component labelling followed by projection method.	Matching of two document fragments based on the characteristics of the matching portion of the two pieces.
Document stitching	IEEE/2013	A Probabilistic Model for Reconstruction of Torn Forensic Documents [8]	A probabilistic method to join hand torn documents is proposed. A seed fragment is chosen and probabilities are generated of all combinations of that seed fragment and other remaining pieces. The process is repeated iteratively and maximum probability value is chosen as output.	To automate the process of image stitching for forensic documents.

IV. CONCLUSION

Studying the papers on the topic of stitching of torn document, it can be inferred that it has its core applications in forensics, historical document prevention, archeology and also in legal documentations of day to day life. The main aim of stitching of torn document is to reconstruct a torn document of any kind from more than one pieces or fragments. It further aims to automate the process of image and document stitching with little human intervention. The current existing algorithms to find the matching pieces need to improve the accuracy and speed of fragment matching. Algorithms also be made such that they automate the image stitching process from little to zero human interventions. Further, quality of reconstructed document still has some scope to improve the techniques giving fine qualities of reconstructed documents.

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