Text Reconstruction using Torn Document Mosaicing

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ABSTRACT
Text extraction from torn documents is a critical process in the field of document reconstruction. Estimation of fragment orientation based on the text orientation is proposed to get an exact rotational angle with x axis. Corners detection with extraction of the pick points is introduced as a basic feature for the boundary matching process. A novel approach of single matched corner identification for finding the corresponding points between two oriented fragments is implemented. Dilation process is used to extract the background of the text from the text image. Removal of background from text image is devised for the clear visualization of seamless text with black or white background which is responsible for making the merging process easy. Shift and Merge method is implemented for positioning of the matched fragments. A function called as a maskblending is utilized to merge the extracted texts from the shifted fragments along masked irregular shape. An experimental result clearly visualizes the different steps of document mosaicing.

Keywords
Document Reconstruction, Text Extraction, Corner Detection, Boundary matching.

1. INTRODUCTION
Automatic software based solution to torn paper organization is a major requirement in the field of document reconstruction. Many researchers [1, 2, 3, 4] undergone the different aspects of document and text reconstruction. The techniques like text document reconstruction and text reconstruction from torn document not only requires extracting the shape of the boundary but also requires extracting the texture of the inner most text area for its reconstruction. Text reconstruction needs to deal mainly with the orientation, boundary matching and text extraction from torn pieces (fragments). Recently [3, 4, 5, 6] introduced the text reconstruction from the torn document. Florian [7] estimated the global orientation using the accumulation of gradient orientation of each pixel into the orientation histogram. Estimation of gradient orientation is a more complex technique. Simple and efficient estimation of fragment orientation based on the text orientation is introduced in this work. Blurring of the text is made advantageous for estimation of orientation of text. Lines along the boundary of blurred texts can be used to estimate the orientation.

Matching of the boundaries is one of the critical steps in the torn paper reconstruction. We proposed corner based exterior boundary matching for finding exact connectivity between the two torn pieces. As every piece is considered as a unique, its boundaries along corner points are also taken as unique and can be taken as a main parameter for finding connectivity between many pieces. In every torn fragment, corner points are most distant points from its centroid point and they are always common to many different pieces. Along these corner points, boundaries can be matched. Multi-scaled Shape Contest Boundary Matching [1] is used to get a final and exact match. Because of the proper orientation of two pieces, only a single matched corner point is required to be identified for matching all the corresponding points of two fragments. Based on this logic, the proposed matching process is designed.

Algorithms for background extraction [8, 9, 10] can be used for extraction of text from image/video. We used the dilation based background and text extractions because of enlargement, simple and efficient properties which are useful for text extraction without seam boundaries. Text extracted without seam boundaries removes the background of image and it is totally replaced by the black or white background. So, merging along the black or white background with text is similar to the merging of binary image which can provide better results than the color image merging. Difference of text image and its dilated image [11] extracts the texts from gray or color text image, as dilated process is a background extraction process for the given image.

The combination of selected portions of two different images is not so easy like the cut and paste operation of these portions. Cutting operation of the image is a totally manual process and can cut the rectangular portion only. Irregular shape cutting/segmentation algorithms [12, 13, 14] were developed by different researchers but the problem of visible seam line is not solves so, different merging techniques [15, 16, 17, 18] were introduced. Ghosting [15] and non-linear blending [16] problems of merging of two images were solved but these processes are computationally more complex. The process which is fast and gives proper results is required for the merging of two images. Masked Irregular Shape Blending Algorithm [19] is suitable for our work as it merges the irregular shapes of two images.

Extraction of orientation of all the torn pieces and extraction of their corner edges are the processes which are required to perform during the identification of matched piece to the first selected piece (may call first iteration). Individual geometrical parameters of all the torn pieces are extracted during this initial process. These parameters can be used during the identification of matched pieces to the remaining pieces. So, the datasets are created during the first iteration. It is required to store the

extracted geometrical parameters of every fragment into the datasets so that it can be utilized in next iterations. This makes the next iterations computationally less complex. As the boundaries of each fragment have to be matched to the boundaries of all other fragments, recursion and repetition of the process is required.

2. METHODOLOGY

As the number of torn fragments increases, complexity and error of finding connectivity also increase in the case of torn paper reconstruction. So, a software based solution is recommended by many authors [3, 4, 5, 6, 7] for real reconstruction. We introduced a novel approach of text reconstruction using torn paper mosaicing in which torn fragments are reconnected to each other and text is extracted for reconstruction.

General steps involved are,

1. Orientation of all the fragments according to the orientation of text.
2. Extraction of corners of all the fragments.
3. Estimation of geometry of all the corners.
4. Initial-matching of each corner with all the corners of other fragments with the use of proposed Half-quadrant Matching and Adjacent Corner Matching methods. All the non-matched corners are rejected.
5. Final-matching of non-rejected initially matched corners with Multi-scaled Shape Content based Boundary Matching technique. It finds a maximum-matched corner between the two fragments.
6. Text extraction from all the oriented fragments.
7. Combination of two fragments corresponding to the matched corners.

2.1 Geometric Orientation Extraction with Blurred Text

Inline words are the general property of text documents. We have taken the advantages of this property for estimation of the fragment orientation on the basis of the orientation of text words.

Every fragment is blurred to destroy the text but the blurring effect can find the boundaries of words. The lines drawn along the text boundaries are always in parallel with each others. Orientations of all the parallel lines can estimate the global orientation of that fragment. Fig. 1(a) shows the original fragment image and Fig. 1(b) illustrates the oriented image using the proposed method.

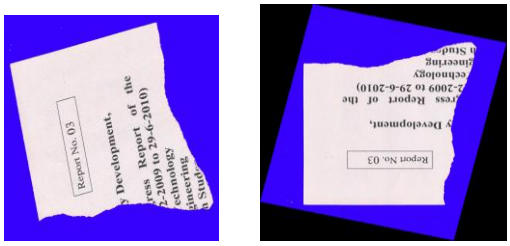


Fig.. 1. a. Original fragment image b. Oriented image

2.1.1 Line Detection

The line detection process includes filtering, edge detection and Hough's transform processing of images. AnisoTropic Diffusion Filtering [20] and Marr Hildreth Edge Detector [21] processes are useful to get better performance to line detection.

2.1.1.1 AnisoTropic Diffusion Filtering

Darken side edges may be missing if Median like filter is used. AnisoTropic Diffusion filtering preserves it. Although it creates a blurred effect, it can provide best edges for line detection [20]. It intentionally blurs the image to smooth out the small lines so that it can capture the long lines in the image using the edge detector.

2.1.1.2 Marr Hildreth Edge Detector

The Marr Hildreth Edge Detector [21] gives multiple edge lines as compared to a much better edge using the canny edge detector. This is because canny uses Hysteresis Thresholding and Non Maximal Suppression. The Marr Hildreth Edge Detector gives edges which have a typical sphagetti like look. However, all the straight lines are still recoverable from the edge image. A good property of Marr Hildreth edge detector is that it gives closed loops for every edge which is not true for the canny edge detector.

2.1.1.3 Line Detection using Hough's Transform

Edges of a selected image are detected using Marr Hildreth edge detection after filtering the image with an AnisoTropic Diffusion Filter. Hough transform [23, 24] is applied to the randomly selected edges to determine the line equations. The lines are plotted on the image with the use of line equations.

2.2 Extraction of the corners of fragments

As the corners are the maximum distant points along the boundary of fragments from its centroid, it can be considered as the characteristic points for the fragments matching. Precisely extracted corner point may be the matched corner points of adjacent fragments. Different steps of corner extraction are 1) boundary detection 2) centroid estimation 3) extraction of pick distant points as corner points. Boundary detection using L*a*b* color spaces [25] is the precise and accurate process and is suitable for separation of different colored areas. Centroid [11] of the image region is approximately equidistant point from all the boundary points of the image region. The maximum distant point on the boundary from the centroid is first pick but second (or next) maxima may not be a second (or next) pick. A particular pick is always associated with neighbor minima on its both sides.

2.2.1 Boundary Detection

Any color image segmentation algorithm with torn piece images, captured with a high resolution camera with dark background, easily and exactly segments the external dark color from the internal color of the image around the boundary. Segmented color images are useful in order to extract exact boundary.

L*a*b* color spaces [25] based color image segmentation algorithm [26] is used for exact extraction of dark colored portion (External Boundary Portion) from the captured image. It separates the selected colors into the different color images. 8-Connected neighborhood boundary detection technique [28] finds the boundary along the torn edges using dark color segmented images.

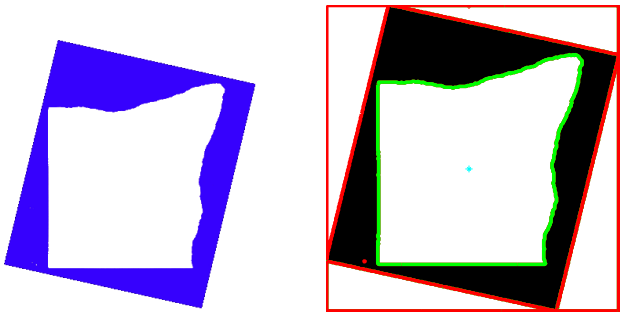


Fig. 2 a. L*a*b* Color spaces segmented image b. Boundary extracted

L*a*b* color spaces based color segmented image is shown in Fig. 2(a) and corresponding boundaries are visualized in Fig. 2(b).

2.2.2 Extraction of Pick Distant Points

Corner points are the points at pick distances between the centroid and all the boundary points. Pick points are the maximum distant points with respective to their neighbor points on the boundary. Out of all the corners, minimum 4 or 5 points are generally sufficient for finding the connected between two fragments. Fig. 3 illustrates picks on the distance graph. The distance graph is the graph of distances between boundary points and centroid verses boundary points. Detected corners are shown in Fig. 4.

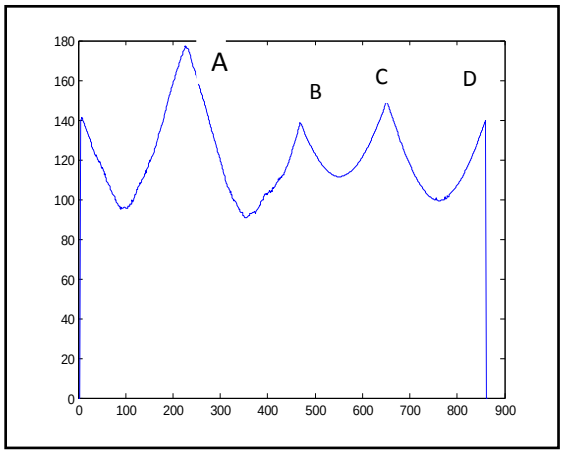


Fig. 3. Distance Graph

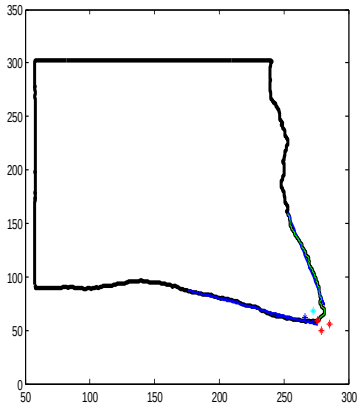


Fig. 4. Detected corners

2.3 Estimation of Corner Geometrical Features

Let L1, L2 be the lines passing through a corner point and fitting along its neighbor boundaries (b1, b2) in its both sides are initially estimated as an equivalence of both the boundaries. Half-quadrants (e.g. q12 indicating 2nd half of 1st quadrant) of lines (L1, L2) and angle between them are considered as the Corner Geometrical Features. Both the features are used to match the corners of different fragments during the initial matching process.

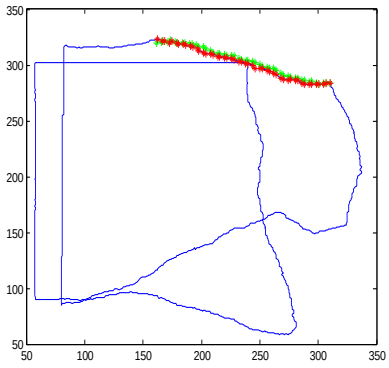
2.4 Initial Features based Corner Matching

Initial matching of each corner contributes two techniques as, 1) Half-quadrant Matching and 2) Adjacent Corner Angle Matching. Both the matching techniques are based on two criteria as, 1) Boundary (or fitted line say L1) of a particular half-quadrant (say q11) of one fragment along its corner point is always inline to the boundary (or fitted line say L1^1) of opposite half-quadrant (say q31) of connected fragment along its matched corner and 2) angle between two boundaries (say α between lines L1 and L2) along a corner is always 180 degree apart from that of angle (say α^1) of connected fragment along its matched corner. However, as the boundaries along the matched corners are not exactly matched always because of torn edges, system designed must be on the approximation basis. So, the first criteria should be modified as, the boundary of half-quadrant q11 of one fragment along a corner may be inline to the boundary of either q31 or q22 or q32 (adjacent half-quadrants of q31). The second criteria will become as, angle α along a corner may be (180 +/- Tolerance angle) degrees apart from α^1 of connected fragment along its matched corner.

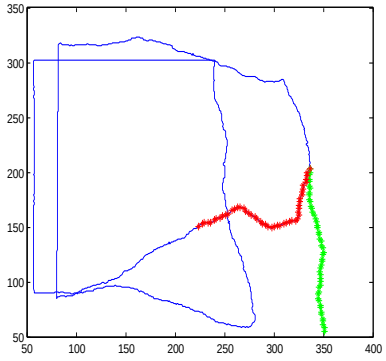
Every extracted corner of each fragment is checked for its corresponding matched corner of other fragments with the use of both the matching techniques. Non-matched corners are rejected and matched corners are accepted for further refining with final matching.

2.5 Final Corner Matching

For getting proper connectivity between two fragments, minimum one matched corner must be identified. Multi-scaled Shape Content based Boundary Matching technique [1] is utilized for the boundary matching along all the corners of two fragments. Because of the irregular shape of boundaries, unexpected matching may be identified with the use of Shape Contest based Boundary Matching technique [29]. To overcome this problem, Multi-scaled Matching is adopted. The process of Shape Content based Boundary Matching is repeated with different levels (scales/length of boundaries) to check its correctness. However, during the first level of this process, if any corner is wrongly matched, it can be corrected during next levels of matching. Maximum time identified corner during all the levels of the process is called a final identified / matched corner.



a.



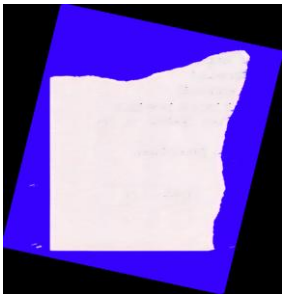
b.

Fig. 5. a. Matched boundaries b. Non-matched boundaries

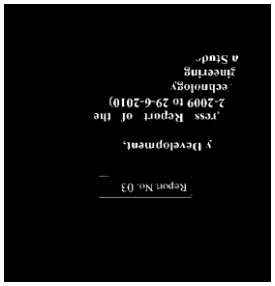
2.6 Text Extraction from Fragment

Text extraction uses the dilation process [11] of the image. Text can be extracted by subtracting the dilated image from grayscale image. Dilated images may be like erased image written with pencil on paper. This image also looks like the image of the background around the text. So, text can be extracted by subtracting the background dilated image from the original image. Fig. 8 shows a dilated image, extracted text with and without boundary images. Extracted text image (Fig. 8 (a)) visualizes the content text and its boundary. Irregular Shape Mask Blending Algorithm [19] is used to remove the boundaries of text image. Mask (Black and While) is formed from the boundary of fragment. Irregular Shape Mask Blending Algorithm with mask of the fragment and the extracted text image creates the text image without boundary (Fig. 8 (c)).

a.



b.



c.

Fig. 8. a. Text extracted b. Dilated image c. Text without boundary

2.7 Combining the Fragments using Shift and Merge method

Connectivity of two torn fragments can be obtained if they are connected to each other along a perfectly matched corner between them. So, oriented images of two fragments can be merged along the matched corners. Steps for combining the two fragments are as follows.

1) Initial fragment selected is called as a host fragment and a matched fragment is called as a guest fragment.
2) Host fragment must be the center positioned in the final image so that all remaining fragments can be easily added around it.
3) Shift the guest image to the position such that matched point on the centered host image must be same as that of the guest image. Recollect the coordinates of all the corners of the shifted guest image which can be used for further combining the fragments.
4) Resize the host and the guest images to the equal sizes by kipping fragments shape and size invariant for the purpose of image merging.
5) Masked Irregular Shape Blending Algorithm [19] is used for image merging at the required place.
6) Repeat the whole process for all remaining fragments with the old guest as a new host.

3. EXPERIMENTAL RESULTS

Fig. 9 shows the combined masked images with two and three fragments.

Fig. 9 a. Combined two images b. Combined three images

Extracted texts from two matched pieces as shown in Fig. 10 are combined to get a combined mask and combined text as illustrated in Fig. 11.

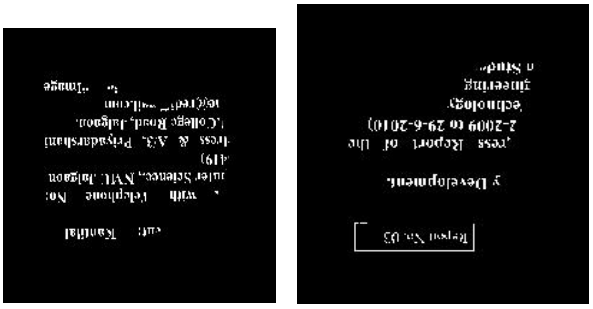


Fig. 10 a. Text from identified piece from all pieces b. Text from initially selected torn piece

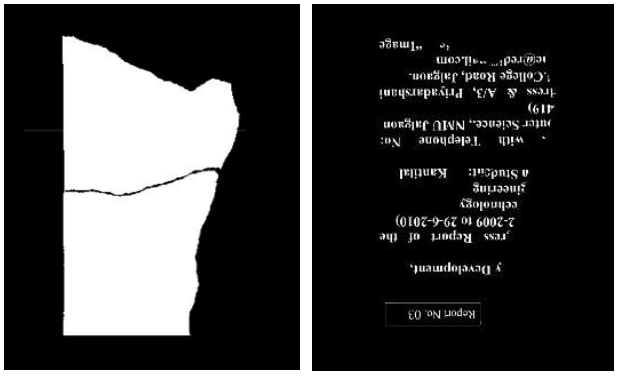


Fig. 11 a. Combined mask from two pieces b. Combined text from two pieces

Combined text from two torn pieces is considered as an initially selected text (piece). A new piece is identified from the remaining pieces using a maximum match with the identified pieces (previously selected pieces during previous iterations). Second identified piece in a match with the initially selected piece is shown in Fig. 12 (b) and combined text with the text of three pieces is shown in Fig. 12 (a).

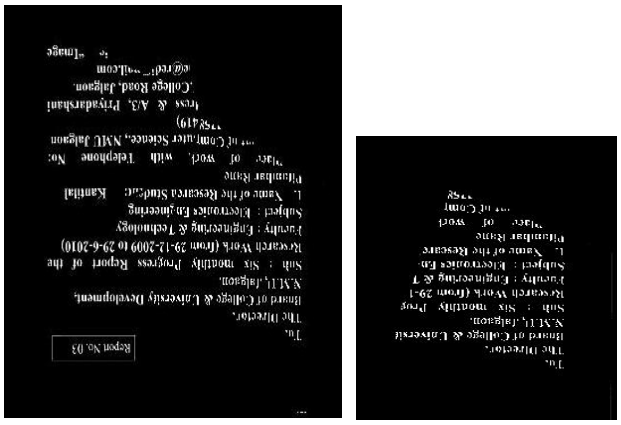


Fig. 12 a. Combination of three pieces b. Second identified piece

Identification of new pieces from the remaining pieces and its combination into the combined text is repeated for the remaining pieces to get a final mosaic text reconstruction. Final mask reconstructed is shown in Fig. 13 and the final combined reconstructed text is shown in Fig. 14. The properly orientated text document is shown in Fig. 15 which has clearly readable and properly aligned contents.

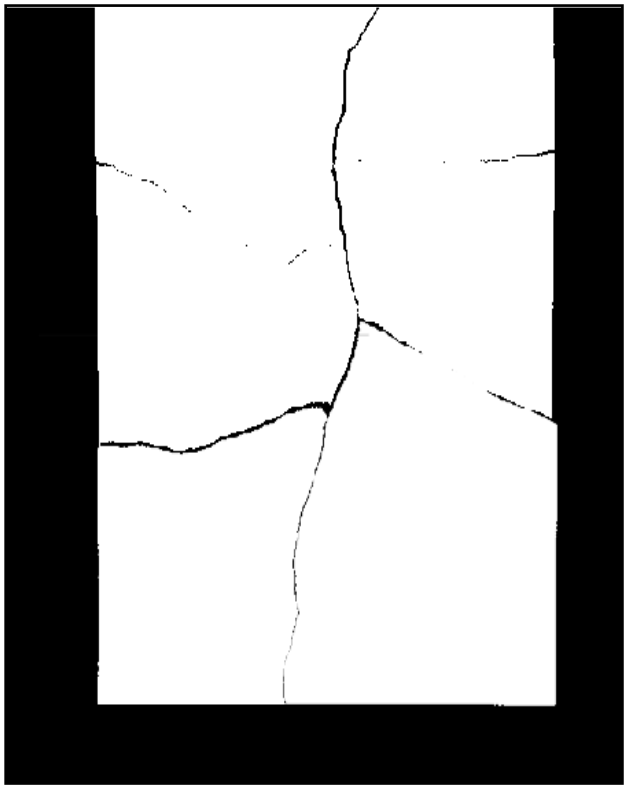


Fig. 13. Final reconstructed mask

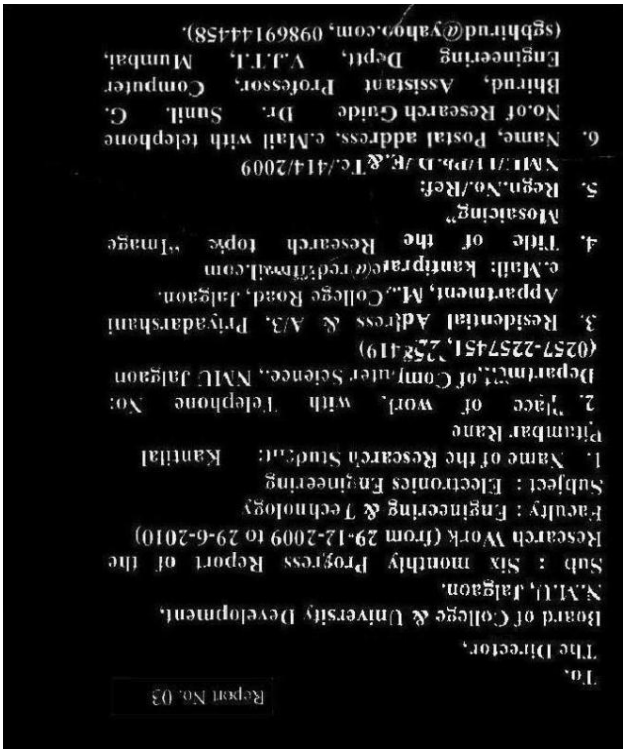


Fig. 14. Final reconstructed text document

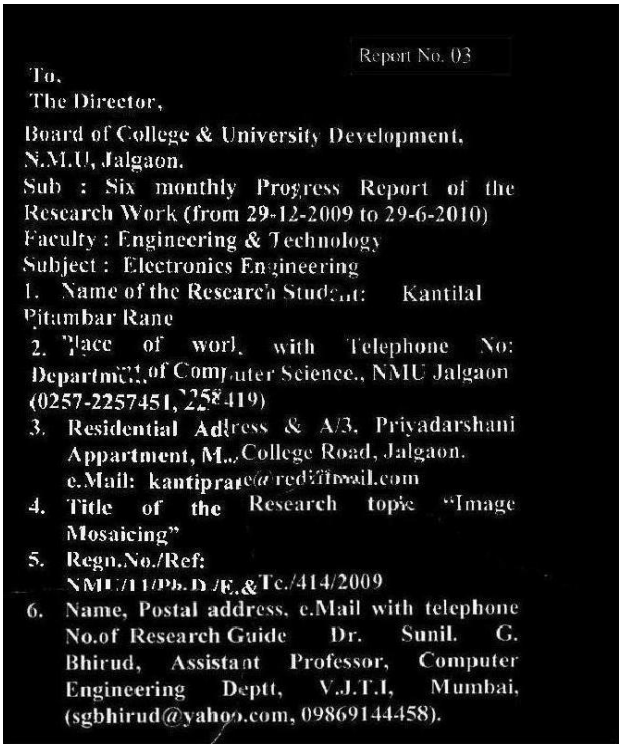


Fig. 15. Final reconstructed text document

4. CONCLUSION

Text reconstruction problems are addressed in this work. Orientation of fragments and matched points extractions are the common problems in this field. Extraction of orientation is possible with proposed Blurred Text based Geometric Orientation Extraction process. Corner matching based on initial features is proposed for an initial match and exact matching with Multi-scaled Boundary Matching technique is implemented for the final match. All the proposed processes are very simple, efficient and accurate processes and can provide better results. Fully automatic text reconstruction and torn paper mosaicing can be obtained with iterative steps of proposed methods.

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