Overview

- To imitate the reconstruction procedure followed by Human Visual System (HVS).
- Human Visual System → High Curvature points and Edge Variations
- Reconstruction of torn document using a unique feature, Edge Envelope.
  - Mapping from two-dimensional spatial co-ordinate points to one-dimension
  - Captures Edge Variations using High Curvature points to imitate HVS.
- Normalized Edge Envelope Difference (NEED) → Effective quantitative measure for matching the edges
- Matching of Edges in time domain rather than in space domain.

Proposed Algorithm

- Preprocessing phase
  - Background estimation
  - Threshold computation using histogram
  - Binarization
  - Canny edge detection
  - Contour tracking
  - Corner point detection using bending value and spurious corners are removed using angle threshold.
- Matching Phase
  - HVS finds the one-to-one similarity by comparing the edge patterns of the torn pieces
  - In a similar way, the degree of similarity between Edge Envelopes is compared using NEED
    \[ \text{NEED} = \frac{1}{2} \sum_{j=1}^{n} |E_i(j) - S_i(j)| \]
    \[ M = \max(\text{length}[E_i(j)], \text{length}[S_i(j)]) \]
    \[ S_j(j) \to 1\text{-D mapping of } E \text{ edge envelope of the torn piece } i \]
    \[ S_j(j) \to 1\text{-D mapping of } S \text{ edge envelope of the torn piece } i \]
  - Edge envelopes are filtered to remove digital imperfections during scanning or shearing
  - Lower the value of NEED, better is the degree of similarity
  - The outcome of matching phase is the matched edges of the torn pieces that are to be joined to get a single reconstructed document
- Joining Phase
  - Matched edges of the torn pieces may have different orientations because of the positioning of the torn pieces during scanning
  - To join the pieces, it is required to rotate and translate the pieces under consideration. This requires the computation of rotation and translation parameters.
  - Rotation Angle \( \theta = \tan^{-1} \left( \frac{CP_j(1) - CP_i(1)}{CP_j(0) - CP_i(0)} \right) \)
  - Translation Parameters \( T = \frac{1}{2} \left[ \left| CP_j(1) + CP_i(1) \right| - \left| CP_j(1) - CP_i(1) \right| \right] \)
  - Conclusions and Future Work
  - A new novel technique for reconstruction of document ripped-up by hand is proposed using a feature, Edge Envelope.
  - Filtering of Edge Envelopes overcome the ambiguity created due to shearing, during matching of edges.
  - A newly defined parameter NEED proves to be an effective quantitative measure for matching the edges of torn pieces.
  - Even in spite of using a single feature, the proposed algorithm is able to reconstruct the document ripped-up by hand very effectively and is demonstrated through preliminary results by taking limited amount of torn pieces.
  - Automatic reconstruction of a document from larger number of torn pieces from single and multiple pages is the scope of future work.

Feature Extraction

- HVS uses the edge variations of torn pieces for matching with its counterpart.
- Akin to that, edge variation between the two corner points is captured and is referred as Edge Envelope.
- The mapping of two-dimensional spatial co-ordinate points to its one-dimensional Edge Envelope is as follows
  \[ a_i = \tan \left( \frac{CP_i(1) - CP_i(0)}{CP_i(0) - CP_i(1)} \right) \]
  \[ a_i = \tan \left( \frac{CP_i(1) - CP_i(0)}{CP_i(0) - CP_i(1)} \right) \]
  \[ \theta = \cos^{-1} \left( \frac{u \cdot v}{\| u \| \| v \|} \right) \]
  \[ \theta = \cos^{-1} \left( \frac{u \cdot v}{\| u \| \| v \|} \right) \]

Conclusions and Future Work

- For our experiments, we have used torn pieces of document and book.
- Two set of such scanned images of torn pieces and their respective reconstructed documents are shown for illustration.
- The typical edge envelope \( S' \), with its matched \( S \) and unmatched \( S' \) counterpart are shown.