Simple, random, and skilled are types of signature forgeries. Simple forgers know the signer's true name but not their authentic signature. In random forgeries, the forger knows the signer's name or signature but uses their own. In skilled forgeries, the forger knows the signer's name and authentic signature and often imitates both. (Hameed, 2021)

**I. Dataset**

**II. Preprocessing**

* The aim of preprocessing techniques is to enhance the images quality and eliminate the inconsistencies of the signature images. The general preprocessing techniques includes binarization, thinning, noise removal, bounding box, segmentation, inversion, and normalization.
* It is necessary to preprocess the signature images before feature extraction due to the variations found in the signature images, even the signature of the same signer, such as the thickness of the pen, stroke embellishments, translation or relative stroke position, rotation, and scaling.
* Large part of the research has used a combination of preprocessing techniques to remove the inconsistencies in the signature images.
* **Binarization** was the most common technique as it is found beneficial to remove the complexity in signature image. It separates signature’s pixels into background and foreground.
* **Thinning** was also another popular method for preprocessing as line thickness variation is a common problem in OfSV. Thinning solves this issue by eliminating thickness differences by making the signatures one-pixel thick.
* **Noise removal** techniques removes random noise from signature images using various image filters, it also preserves the features of the original signature image
* **Bounding box** preprocessing were used to crop the region of interest from the signature image. It removes irrelevant areas, and it only retains the most important and discriminative features from the signature image.

**III. Feature Extraction**

* Feature extraction in the context of OfSV is the process of transforming raw pixels of a signature image into a feature vector by creating new features from the original features (Pixels of whole image). Finding the best feature representations is essential for creating an effective OfSV systems as it helps in the efficiency and accuracy of the system.
* There are two types of feature extraction process either manually or automatically. In Manual method, the most frequently adopted were structural, statistical, texture, geometric and global transformation.

1. Structural Features defines the structural features of a signature image, which includes the intersection of two lines, an open-end corner or a pixel surrounded by space in the signature image. For different characters in the signature image, there are unique intersection features (also called feature points), which are used to recognize individual character.  
     
   **Advantage**: It can be trained with small training data and requires less memory and computation time  
     
   **Limitation**: These features are difficult to extract and have a low accuracy rate. The extracted feature vector is application-oriented, and domain expert need to define manually.  
     
   **Related Documents:**
2. Statistical Features provide a comprehensive view of grey-level or intensity information, derived from statistical distributions of image pixels.  
     
   **Advantage**: It takes care of variations in style with low complexity and high speed. Pattern from different classes is well separated and produces compact pattern set  
     
   **Limitation**: If we have a restricted amount of information, it is sufficient for a direct solution but is insufficient for solving a more general
3. Texture Features are feature that is used to divide the signature image into various regions for classification.  
     
   **Advantage:** It does not lose image information during the extraction process. It takes less computation and more robust.  
     
   **Limitation:** It is sensitive to noise and distortions.
4. Geometric Features describes the geometrical and topological properties of the image while preserving the local and global features. These features can tolerate distortion, variations in style, variations in rotation and a certain degree of translation in the signature image.  
     
   **Advantage:**  Its extraction process is faster than texture-based methods. Relationship between the components in shape is highly expressed.  
     
   **Limitation:** Non-planar feature geometry continues to pose challenges for recognition techniques.

Q5 – Performance Evaluation Metrics