**MODULES:**

* Am-Fm Fingerprint Model
* Dictionary Construction
* Orientation Field Reconstruction
* Fingerprint Reconstruction
* Fingerprint Image Refinement

**MODULE DESCRIPTION:**

**Am-Fm Fingerprint Model:**

The AM-FM fingerprint model proposed by Larkin and Fletcher represents a fingerprint image *I* as a hologram, *i.e.*, consisting of 2D amplitude and frequency modulated fringe pattern: *I (x, y)* = *a(x, y)* + *b(x, y)* cos*(ψ(x, y))* + *n(x, y),* (1) where *a(x, y)*, *b(x, y)* and *n(x, y)* are, respectively, the offset, amplitude and noise, which make the fingerprint realistic, and *ψ(x, y)* is the phase which completely determines the ridge structures and minutiae of the fingerprint.

**Dictionary Construction:**

*1) Orientation Patch Dictionary:* The orientation patch dictionary proposed by Feng et al. for latent enhancement is directly utilized as prior knowledge of ridge flow for orientation field reconstruction. The orientation patch dictionary *DO*, consisting of a number of orientation patches, is constructed from a set of high quality fingerprints (50 rolled fingerprint images). An orientation patch consists of 10×10 orientation elements with each orientation element referring to the dominant orientation in a block of size 16 × 16 pixels.

*2) Continuous Phase Patch Dictionary:* The continuous phase patch dictionary, which includes a number of continuous phase patches (without spirals), is constructed through the following steps: i) Fingerprint selection and processing, ii) Orientation patch clustering, iii) Fingerprint patch clustering, iv) Orientation and frequency fields estimation.

**Orientation Field Reconstruction:**

The orientation field is considered only in the foreground region of a fingerprint which is determined by dilating the convex hull of the input minutiae points with a disk-shape mask with a radius of 32 pixels. The image is divided into non-overlapping blocks of size 16 × 16 pixels. For the blocks containing minutiae, their orientations are simply replaced by the directions of their corresponding minutiae (modulated by *π*). Since the minutiae points are usually non-uniformly distributed (sparsely distributed in some regions), it is difficult to select representative orientation patches from *DO* in the region without minutiae or with one or two minutiae. Orientation patch dictionary, therefore, cannot be used to reconstruct the orientation field directly. In order to address this problem, orientation density is introduced, and the orientations of blocks with low orientation density values are interpolated iteratively using Delaunay triangulation.

**Fingerprint Reconstruction:**

The continuous phase patch dictionary is used to reconstruct fingerprint image patches based on the reconstructed orientation field and ridge frequency field. Global optimization is then adopted to obtain the reconstructed fingerprint image.

1. *Fingerprint Patch Reconstruction:* For a patch *p* of size 48 × 48 pixels in the initial image (only the reconstructed orientation field and ridge frequency field are available), its orientation field *θp* with 3 × 3 blocks and average frequency *f p* are obtained from the reconstructed orientation field and frequency field. The minutiae can be added by combining the continuous phase patch and the spiral phase computed from the minutiae in a patch.
2. *Fingerprint Image Reconstruction:* The fingerprint image reconstruction can now be viewed as a combinatorial optimization problem similar to fingerprint orientation reconstruction.

**Fingerprint Image Refinement:**

We adopt the global AM-FM model to remove the spurious minutiae from the reconstructed image *I.* The block wise orientation field is expanded to pixel-wise orientation field. The orientation unwrapping method proposed in is adopted to obtain the unwrapped orientation field *Ou*. For orientation field with singular points, there are horizontal discontinuity segments, which will introduce discontinuity in the unwrapped orientation field and then in the phase image. After all discontinuity segments have been considered, Gabor filtering is used to smooth the fingerprint region around these discontinuity segments, and demodulation is used again to obtain the final phase image and then final reconstruction.