Real Time Adaptive Face Recognition – Under the Hood

Online Algorithm

Inputs:
- an unlabeled example \( x_t \)
- a quantized data adjacency graph \( W_{t-1} \)
- vertex multiplicities \( v_{t-1} \)

Algorithm:
- if the graph \( W_{t-1} \) has less then \( n_g \) vertices, add a new vertex \( x_i \) to the graph \( W_{t-1} \)
- \( v_t(l) = v_{t-1}(l) \) for \( l = 1, \ldots, t - 1 \)
- \( v_t(t) = 1 \)
- else
- find the vertices \( i \) and \( j \) that minimize \( v_{t-1}(j)d(x_t, x_j) \)
- replace the \( j \)-th vertex of the graph \( W_{t-1} \) with \( x_t \)
- \( v_t(l) = v_{t-1}(l) \) for \( l = 1, \ldots, n_g \)
- \( v_t(i) = v_{t-1}(i) + v_{t-1}(j) \)
- \( v_t(j) = 1 \)
- \( W_t = W_{t-1} \)
- \( W_t = V_t W_t V_t \)
- compute the Laplacian \( \tilde{L} \) of the graph \( \tilde{W}_t \)
- infer labels on the graph:
- \( \hat{\ell}_t = \arg \min_{\ell} \ell^T(\tilde{L} + \gamma V_t)\ell \)
- s.t. \( \ell_t = y_t \) for all labeled examples up to the time \( t \)
- make a prediction \( \hat{y}_t = \text{sgn}(\hat{\ell}_t) \)

Outputs:
- a prediction \( \hat{y}_t \)
- a quantized data adjacency graph \( W_t \)
- vertex multiplicities \( v_t \)

Online harmonic function solution at the time step \( t \). The main parameters of the algorithm is the regularizer \( \gamma \) and the maximum number of vertices \( n_g \).

Similarity Matrix
- Defined over set of faces, higher weights to the pixels in the center
- \( w_{ij} = \exp\left(-\frac{d(x_i, x_j)^2}{2\sigma^2}\right) \)

where \( d(x_i, x_j) = \min\left\{ \frac{\|x_i - x_j\|_2, 1}, \frac{\|x_i - x_j\| - \|x_i - x_j\|_2, 1}{} \right\} \)

Data Quantization
- Cannot store all the past data
- Similarity graph needs to be reasonably small
- Greedily find the closest pair of nodes
- Represent the two nodes by a single one
- Keep track of multiplicities

\[ \hat{\ell}_t = (\tilde{L} + \gamma V_t)^{-1} \tilde{W}_t \ell_t \]

Regularized Harmonic Solution

Minimum satisfies the harmonic property and has a closed form solution.

Prediction Error Analysis

Quality of quantization

\[ \frac{1}{n} \sum_{t} (\ell_t - y_t)^2 \leq \frac{9}{2n} \sum_{t} (\ell_t - \hat{\ell}_t)^2 + \frac{9}{2n} \sum_{t} (\hat{\ell}_t - y_t)^2 \]

Difference between the offline and online prediction

\[ O(\sqrt{n}) \] by the algorithm stability argument of [Cortes et al. 2008]