Real Time Adaptive Face Recognition – Under the Hood

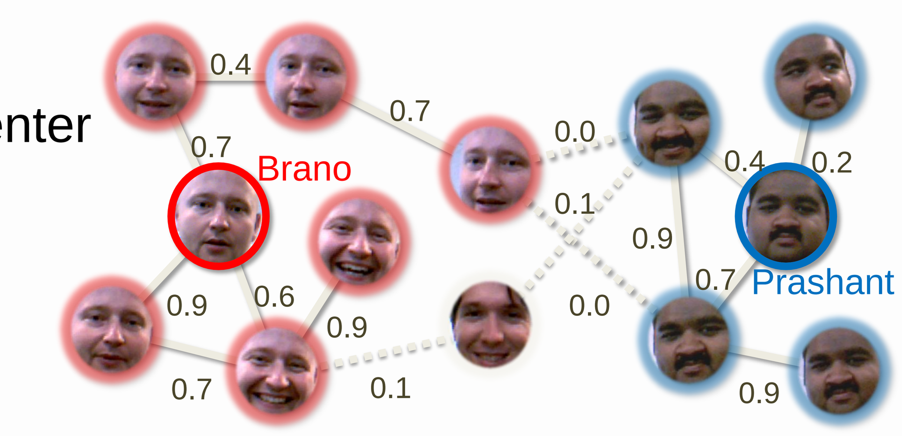
Everyday Sensing and Perception

REAL-TIME LEARNING WITHOUT EXPLICIT FEEDBACK

Similarity Matrix

- Defined over set of faces, higher weights to the pixels in the center
- $w_{ij} = \exp\left[-\frac{d^2(\mathbf{x}_i,\mathbf{x}_j)}{2\sigma^2}\right]$,

where $d(\mathbf{x}_i,\mathbf{x}_j) = \min\left\{ \begin{array}{l} \|\mathbf{x}_i - \mathbf{x}_j\|_{2,\psi}, \\ \|(\mathbf{x}_i - \bar{\mathbf{x}}_i) - (\mathbf{x}_j - \bar{\mathbf{x}}_j)\|_{2,\psi}, \\ \|\mathbf{x}_i/\bar{\mathbf{x}}_i - \mathbf{x}_j/\bar{\mathbf{x}}_j\|_{2,\psi} \end{array} \right\}$



Online Algorithm

Inputs:
- an unlabeled example $\mathbf{x}_t$
- a quantized data adjacency graph W_{t-1}
- vertex multiplicities $\mathbf{v}_{t-1}$

Algorithm:

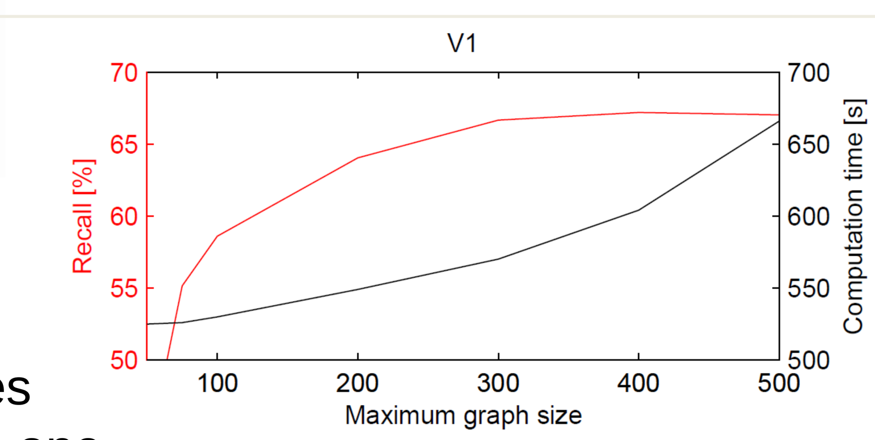
if the graph W_{t-1} has less then n_g vertices
  add a new vertex $\mathbf{x}_t$ to the graph W_{t-1}
  $v_t(l) = v_{t-1}(l)$ for $l = 1, \dots, t-1$
  $v_t(t) = 1$
else
  find the vertices i and j that minimize $v_{t-1}(j)d(\mathbf{x}_i,\mathbf{x}_j)$
  replace the j-th vertex of the graph W_{t-1} with $\mathbf{x}_t$
  $v_t(l) = v_{t-1}(l)$ for $l = 1, \dots, n_g$
  $v_t(i) = v_{t-1}(i) + v_{t-1}(j)$
  $v_t(j) = 1$
$W_t = W_{t-1}$
$\hat{W}_t = V_t W_t V_t$
compute the Laplacian $\hat{L}$ of the graph $\hat{W}_t$
infer labels on the graph:
  $\hat{\boldsymbol{\ell}} = \arg\min_{\boldsymbol{\ell}} \boldsymbol{\ell}^{\mathsf{T}}(\hat{L} + \gamma_g V_t)\boldsymbol{\ell}$
  s.t. $\ell_i = y_i$ for all labeled examples up to the time t
make a prediction $\hat{y}_t = \mathrm{sgn}(\hat{\ell}_t)$

Outputs:
- a prediction $\hat{y}_t$
- a quantized data adjacency graph W_t
- vertex multiplicities $\mathbf{v}_t$

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

Data Quantization

- Cannot store all the past data
- Similarity graph needs to be reasonably small

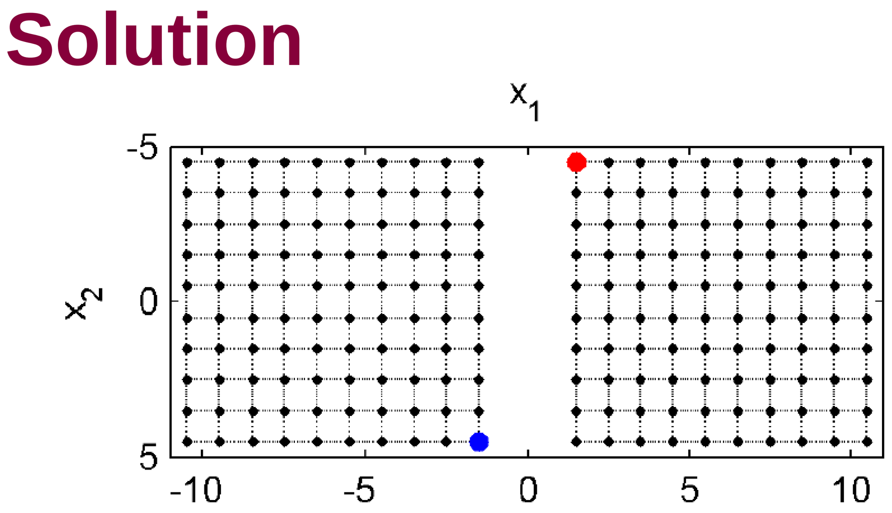


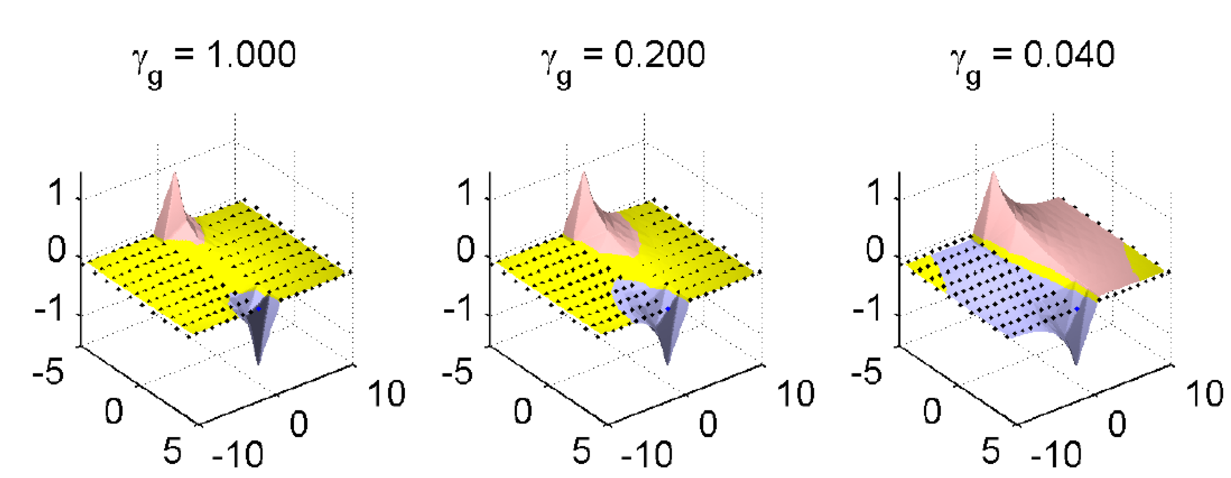
- Greedily find the closest pair of nodes
- Represent the two nodes by a single one
- Keep track of *multiplicities*

$$\hat{\boldsymbol{\ell}}_u = (\hat{L}_{uu} + \gamma_g V)^{-1}\hat{W}_{ul}\boldsymbol{\ell}_l$$

Regularized Harmonic Solution

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





Regularization controls the amount of extrapolation to unlabeled data. The lower the regularizer, the more we trust unlabeled data

Prediction Error Analysis

$$\frac{1}{n}\sum_t(\hat{\ell}_t - y_t)^2 \leq \frac{9}{2n}\sum_t(\hat{\ell}_t - \tilde{\ell}_t)^2 + \frac{9}{2n}\sum_t(\tilde{\ell}_t - \ell_t^*)^2 + \frac{9}{2n}\sum_t(\ell_t^* - y_t)^2.$$

Quality of quantization

Difference between the offline and online prediction

O(√n) by the algorithm stability argument of [Cortes et al. 2008]

PROJECT TEAM

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