Super-Resolution of Face Images

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Introduction

• Main Idea: Learning-Based Super-Resolution
Introduction cont’d

• What we do in this paper:
  – Apply this learning-based super-resolution method to human face images.
  – Compare it with several interpolation-based super-resolution methods.
    • Visual comparison.
    • RMS (Root Mean Square) intensity error.
  – Performance (RMS error) vs. amount of training data.
  – A new face recognition method.
Modeling high-resolution and low-resolution image patches as nodes in a Markov Random Fields (MRF) model.

\[ \Phi(x_i, y_i) \]

\[ \Psi(x_i, x_j) \]
Two phases to solve this super-resolution problem:

• Learning
  – Learning the parameters \((\Phi(x_i, y_i), \Psi(x_i, x_j))\) of the MRF model from the training data.

• Inference
  – Inferring the high-resolution image corresponding to the given low-resolution image using the Belief Propagation (BP) algorithm.
Learning phase:

Learning compatibility function $\Phi(x_i, y_i)$: Assume Gaussian noise takes you from observed image patch to synthetic sample

$$\Phi(x_i, y_i) = \exp^{-|y_i - y(x_i)|^2 / 2\sigma^2}$$
Learning phase:

Learning compatibility function $\Psi(x_i, x_j)$:

Assume overlapped regions, $d$, of high-resolution patches differ by Gaussian observation noise:

$$\Psi(x_i, x_j) = \exp\left(-\frac{|d_i - d_j|^2}{2\sigma^2}\right)$$
Inference phase: Belief Propagation (BP)

BP is an inference method proposed by Pearl (1988) to efficiently estimate Bayesian beliefs in the network by the way of iteratively passing messages between neighbors.

\[
M_i^j(x_i) = \sum_{x_j} \Psi(x_i, x_j) \Phi(x_j, y_j) \prod_{k \in N(j) \setminus i} M_j^k(x_j)
\]

\[
b_j(x_j) = \Phi(x_j, y_j) \prod_{k \in N(j)} M_j^k(x_j)
\]

\[
\hat{x}_j = \arg\max_{x_j} b_j(x_j)
\]
(a) High-resolution images

(b) Learning-based method

(c) Nearest Neighbor Interpolation

(d) Bilinear Interpolation

(e) Bicubic Interpolation
Super-Resolution-based Face Recognition

From the result of the BP algorithm, we can easily know the identity of each high-frequency patch $x_{iMAP}$.