Reconstruction of Walking People Images by Principal Component Analysis

iCML 03
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The Reconstruction Problem:

- Given a set of walking people images, project them into feature space. Only keep the first k dimensional information and reconstruct these images based on these reduced information.
- If we can find such a good feature space, we can use this feature space to build a good model to represent walking people images.
- My approach:
  - PCA (Principal Component Analysis): Use the principal components of the covariance matrix of the image data to build such a feature space.
PCA (construct feature space)

- Construct featurespace: (eigenspace): given a set of centered vectors (walking people images), \( X_k, k=1,\ldots, M, \) \( X_k \in \mathbb{R}^N \), PCA will diagonalizes the covariance matrix:

\[
C = \frac{1}{M} \sum_{j=1}^{M} X_j X_j^T
\]

- To do this, we need to solve the eigenvalue equation: \( CV = \lambda V \) for eigenvalues \( \lambda \geq 0 \) and \( V \in \mathbb{R}^N \setminus \{0\} \). The eigen vectors \( V \) will be the axes for the feature space. We will order the eigenvectors according to the corresponding eigenvalues. We only need to keep the first \( k \) significant eigenvectors \( V^k \). (Principal Components)
PCA (project to feature space)

- For new image $U \in \mathbb{R}^N$, first center the image, then project it into the feature space:

  $\omega = (V^k)^T (U - \text{mean}(X))$

- The $\omega$ vector, which is an $N$ dimensional vector, can be seen as the new image encoding of the image in the feature space.

- Reconstruction:

  $U' = V^k \omega + \text{mean}(X)$
Experiment results:

- Original image:

- Reconstruction from PCA:

  (From left to right, k is increased from 1 to 9)
Experiment result:

- We use the error between the reconstructed image and original image to measure the reconstruction.
- Reconstruction of the testing images:
Experiment Results

- Reconstruction of training images:

![Plot of reconstruction error from training images](image_url)
Conclusion:

- PCA is a good approach to extract features from data and therefore, a good way to build model for walking people’s image.
- PCA is a linear approach, which can not represent the non-linear features in the data. Some improved version of PCA, such as kernel PCA, might be a good complement for it.