

Learning of Graph Compressed Dictionaries for Sparse Representation Classification

Farshad Nourbakhsh and Eric Granger

*Laboratoire D'Imagerie de Vision et D'Intelligence Artificielle, École de Technologie Supérieure,
Université du Québec, Montréal, Canada*

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Abstract: Despite the limited target data available to design face models in video surveillance applications, many faces of non-target individuals may be captured over multiple cameras in operational environments to improve robustness to variations. This paper focuses on Sparse Representation Classification (SRC) techniques that are suitable for the design of still-to-video FR systems based on under-sampled dictionaries. The limited reference data available during enrolment is complemented by an over-complete external dictionary that is formed with an abundance of faces from non-target individuals. In this paper, the Graph-Compressed Dictionary Learning (GCDL) technique is proposed to learn compact auxiliary dictionaries for SRC. GCDL is based on matrix factorization, and allows to maintain a high level of SRC accuracy with compressed dictionaries because it exploits structural information to represent intra-class variations. Graph compression based on matrix factorization shown to efficiently compress data, and can therefore rapidly construct compact dictionaries. Accuracy and efficiency of the proposed GCDL technique is assessed and compared to reference sparse coding and dictionary learning techniques using images from the CAS-PEAL database. GCDL is shown to provide fast matching and adaptation of compressed dictionaries to new reference faces from the video surveillance environments.

1 INTRODUCTION

In the recent years, sparse modelling has become an important tool in the pattern recognition and computer vision communities. They have been successfully applied in many image/video processing tasks like face recognition, image denoising and super-resolution (Mairal et al., 2014). The well-known Sparse Representation Classification (SRC) techniques (Wright et al., 2009) typically need a sufficient amount of representative training data to construct over-complete dictionaries that can provide a high level of performance. In many real-world applications, the number of reference images that are available for system design is limited. Classification systems designed with few reference samples per class are less robust to the intra-class variabilities encountered during operations.

In video surveillance, the amount of reference stills and videos captured during enrolment to design a face recognition (FR) system is typically limited, especially in watch-list screening applications (Dewan et al., 2016). The still-to-video FR systems employed

for watch-list screening seek to match probe face images captured using surveillance cameras against the reference still images of each individual of interest enrolled in the gallery. The appearance of faces captured under uncontrolled conditions using surveillance cameras, varies due to changes in illumination, pose, expression, scale, blur, etc., and divergence from gallery images.

To enhance the robustness of facial models to intra-class variability, the methods proposed for Single Sample Per Person (SSPP) problems (Tan et al., 2006) performs FR using multiple synthetically generated reference faces from an original reference image (Mokhayeri et al., 2015), multiple face representation (Bashbaghi et al., 2014), and external data captured from individuals in the operational environment (Su et al., 2010). In video surveillance applications, the faces of many unknown non-target individuals may be captured in the operational environment, and over multiple cameras, to improve robustness to intra-class variations. This paper focuses on techniques based on under-sampled dictionary of still

reference faces that are appropriate for the design of still-to-video FR systems. The lack of target reference facial samples available to design face models is compensated by using an over-complete external dictionary that is formed based on non-target individual captured in the operational environment.

Some techniques in SRC have been developed to utilize such external data. For instance, Extended SRC (Deng et al., 2012) was one of the first methods that modified SRC framework to achieve benefit of external data on under-sampled dictionary. RADL and SVDL (Wei and Wang, 2015; Yang et al., 2013) are more recent techniques on sparse modelling that combine dictionary learning and classification to manage external data more efficiently.

One of the main drawbacks of using large external data is storage and computational time. The time and memory complexity is proportional to the size of dictionary $|D|$. Dictionary Learning (DL) techniques are a possible solution to build a compact representation of the large external data (Mairal et al., 2014). DL techniques used by researchers in SRC in recent years can be categorised into structural, hierarchical and topological techniques (Shafiee et al., 2013). For instance, K-Means Singular Value Decomposition (K-SVD) is a common method (Aharon et al., 2006) to learn dictionary from external data. It is worth to mention that although DL techniques provides a compact representation of data, they are not necessarily time efficient. It has been shown that learning a dictionary based on sparse representation is NP-hard (Tillmann, 2015).

One way to reduce memory and time complexity, and increase accuracy is data compression (Choi and Szpankowski, 2012; Navlakha et al., 2008; Toivonen et al., 2011) as applied in big data applications (Nourbakhsh, 2015). Compressing data consists in changing its representation such that it requires fewer bits. Lossy or lossless compression are possible depending on the reversibility of encoding. Many graph compression methods have been proposed in literature with a different focus, e.g., information theoretic approach, partitioning as a regular pairs and summarization of data. A graph compression method is suitable for preprocessing of SRC methods that provides cluster-based compactness.

Nourbakhsh et al. (Nourbakhsh et al., 2015) have proposed a graph compression method based on matrix factorization that focuses on structural information. Data is presented as a similarity matrix of n data samples, and matrix factorization encodes the order of graph data into a compressed graph of order $k \leq n$ in a way to minimize reconstruction error. It has been shown that this data compression method reduces the

complexity of many algorithms from n^2 to $(k^2 + n)$ by replacing the original data with its corresponding factorization. Although this method has not been developed for graph clustering, practical results suggest that it provide a potentially powerful preprocessing tools for DL and SRC.

In this paper, a new graph compression technique based on matrix factorization is proposed to learn compact auxiliary dictionaries for accurate SRC. This techniques, entitled Graph-Compressed Dictionary Learning (GCDL), allows to maintain a high level of accuracy with compressed dictionaries because it exploits structural information to represent intra-class variations. In addition to providing fast matching, graph factorization compression has been shown to efficiently compress data, and can therefore rapidly construct compressed dictionaries compared to many reference DL methods. It is therefore suitable for adaptation of compressed dictionaries to newly-acquired reference faces captured in changing video surveillance environments.

2 SPARSE REPRESENTATION CLASSIFICATION

In sparse modelling, probe samples are represented as sparse linear combination of reference samples. The sparse representation of a signal can be formulated under the assumption that the samples from a single class lie on a linear subspace. Given an over complete matrix $\mathbf{D} = [D_1, D_2, \dots, D_l]$ with the l distinct classes. The size of over complete dictionary is $m \times n$, where the size of column is greater than the size of row, and usually $n \gg m$. The i th class of \mathbf{D} can be presented as $D_i = [d_{i,1}, d_{i,2}, \dots, d_{i,n_i}]$ with a size of $m \times n_i$. The probe sample y with a size $m \times 1$ from class D_i will lie in the linear span of over complete dictionary as below:

$$y = a_{i,1}d_{i,1} + a_{i,2}d_{i,2} + \dots + a_{i,n}d_{i,n_i}, \quad (1)$$

where $(a_{i,1}, \dots, a_{i,n})$ are the linear representation of y on the over complete dictionary, defined as,

$$y = [D_1, D_2, \dots, D_l]x. \quad (2)$$

where x is a sparse coefficient vector. The entries of x are always zero, except for the ones belong to the i th class.

In the real FR application because of the presence of factors such as noise, the linear Eq (2) is not determined when there is no unique solution. It is possible to resolve this issue, using sparse representation of probe sample by increasing the value of l . Using sparse representation, the natural solution is applying

l_0 – norm minimization to determine the coefficients that are equivalent to the number of non-zero components in vector x .

$$\hat{x} = \min_x \|x\|_0 \quad s.t. \quad y = \mathbf{D}x. \quad (3)$$

Eq (3) is *NP*-hard and difficult to approximate. By combining compressed sensing (Donoho and Tsai, 2008) and sparse representation theory, an approximate solution is obtained by replacing the l_0 norm in Eq (4) with the l_1 norm:

$$\hat{x} = \min_x \|x\|_1 \quad s.t. \quad y = \mathbf{D}x. \quad (4)$$

If the solution of vector x is sparse enough so the solution of Eq (4) is equivalent as Eq (3). Eq (4) can be solved with different optimization techniques like basis pursuit using linear programming.

In this paper, difference SRC techniques based on (Wei and Wang, 2015) are considered, so some of these are renewed. Eq (5) is a generalized version of Eq (4), which allows for certain degree of noise that is called LASSO (Yang et al., 2010a), it seeks to find x such that the following objective function is minimized:

$$\min_x \|y - \mathbf{D}x\|_2^2 + \lambda \|x\|_1 \quad (5)$$

where $\lambda > 0$ controls reconstruction error and sparsity which is called scalar regularization parameter. When the sparse vector coefficient is obtained by Eq (4) or (5), a probe image y is assigned to a class by calculating the distance between the probe image and the reconstructed image based on sparse vector coefficient. This image indicates the class elements as non zero value and almost zero for non classes. The main idea is when the class is recognized correctly, the query image can be reconstructed linearly with a relevant bases of dictionary \mathbf{D} .

SRC method needs large amount of training to built over complete dictionary and the training data size has a direct effect on the classification. In many real applications like video surveillance, there is not enough reference target training data so one of the solutions is to apply non target external data. (Deng et al., 2012) extended SRC method for undersampled dictionary data. In their method, undersampled dictionary $D = [d_1, d_2, \dots, d_l]$ (\mathbf{D} is overcomplete dictionary) is populated with one or few samples for each class. External dictionary from non target data \mathbf{ED} covers the known distortion like illumination. It adds intra class variation to the undersampled dictionary \mathbf{D} as follow

$$\min_x \|y - [[d_1, d_2, \dots, d_l], \mathbf{ED}] \begin{bmatrix} x_d \\ x_{ED} \end{bmatrix}\|_2^2 + \lambda \|x\|_1 \quad (6)$$

To assign probe image to the closest class, like SRC, the distance calculated between query image

and reconstructed image respect the nonzero coefficient x_d and extra coefficient x_{ED} .

Robust Sparse Coding (RSC) proposed in (Yang et al., 2011b) is a robust face classifier based on SRC. An extra weighting term \mathbf{W} is assigned to each pixel of probe image. Pixels from outlier part of image are less informative than central pixels. For instance eyes and nose of a face have more information than hair. Wei and Wang (2015) have proposed a similar frame work to integrate auxiliary dictionary learning and classification as follows:

$$\min_x \|\mathbf{W}(y - [[d_1, d_2, \dots, d_l], \mathbf{ED}] \begin{bmatrix} x_d \\ x_{ED} \end{bmatrix})\|_2^2 + \lambda \|x\|_1 \quad (7)$$

where \mathbf{ED} is external dictionary. They have proposed two methods $RADL_{wo}$ for classification and $RADL_wDL$ for dictionary learning and classification. In $RADL_wDL$ method, \mathbf{ED} is calculated based on an optimization method on overcomplete external data and each column of learned dictionary \mathbf{ED} is called as **atom**.

3 DICTIONARY LEARNING

The performance of SRC methods is limited by the number of reference samples. For instance, the time complexity respect to the number of sample data is quadratic (Donoho and Tsai, 2008). This challenge has been addressed in the literature by applying a compact representation or reducing the number of reference data. For instance, Wright et al. (2009) has suggested a random selection of reference training sample to reduce the time complexity although it impacts the accuracy. A common solution in literature is to reduce the time complexity of SRC by applying DL techniques although most of them can only be applied off-line because of their time complexity.

Olshausen and Field (1996) introduced dictionary learning in the pattern recognition community (Olshausen and Field, 1996). They proposed an unsupervised method based on data structure that learns the bases/atom of dictionary from training data which is different from classical methods such as discrete Fourier transform (DFT) and various types of Wavelet methods which use fixed standardized format dictionaries. The DL problem can be viewed from different perspectives like matrix factorization, risk minimization and constrained variants.

DL methods have recently been applied as preprocessing step for the SRC. For example Shafiee et al. (2013) have investigated the effect of the impact on performance of three different DL methods for SRC. They used Metaface dictionary learning (Yang et al., 2010b), Fisher Discriminative Dictionary Learning

(FDDL) (Yang et al., 2011a), Sparse Modelling Representative Selection (SMRS) (Elhamifar et al., 2012) to obtain compact representation of training data. They showed that the FDDL method provides a high recognition accuracy compare to other methods although SMRS method requires a less learning time compare to others.

K-Means Singular Value Decomposition (KSVD) (Aharon et al., 2006) and Method of Optimal Directions (MOD) (Engan et al., 1999) are two popular unsupervised DL techniques which have been used in the literature. These EM style methods alternate between dictionary and sparse coding. The difference between these two methods are in dictionary updating, where KSVD updates atom by atom, and MOD updates all the atoms simultaneously.

(Ramírez et al., 2010) proposed a framework to manage sparse modelling and clustering. They introduce set of dictionaries which are optimized one for each cluster. The learned data is a cluster of the union of low dimensional subspaces. Most of the reported DL methods require an overcomplete dictionary to generalize well the intra class variations except (Wei and Wang, 2015; Yang et al., 2013) to some extent. However DL methods based on SR provide a compact representation of overcomplete dictionary that reduces the time complexity of SRCs. However, they are almost *NP*-hard to execute so they are used mostly offline.

4 GRAPH COMPRESSION FOR SRC

Most of DL methods for SRC require considerable amount of construction time that increases with the size of the reference data. To rapidly construct over-complete dictionary without losing dictionary is graph compression which changes the representation of data and requires less memory. Depending on the type of encoding these methods produce a lossy or lossless compression. Data can be presented as a collection of feature vectors or representation of the similarity/dissimilarity relations among data samples. Therefore, it can be easily convert data to the adjacency matrix of a weighted graph. Compression methods can be addressed using information-theory to compress graphical structures (Choi and Szpankowski, 2012) without preventing a graph structure as the compressed representation. As a second category of methods relies on Szemerédi regularity lemma (Szemerédi, 1978) that is a well-known result in extremal graph theory. He roughly states that a dense graph can be approximated by a bounded

number of random bipartite graphs. An algorithmic version of this lemma has been used for accelerating pairwise clustering (Sperotto and Pelillo, 2007). Finally, a compression method can take to account the structural information of data. For example (Navlakha et al., 2008) propose a summarization algorithm for unweighted graphs and (Toivonen et al., 2011) suggested a greedy procedure to determine a set of supernodes and superedges that to approximate a weighted graph.

4.1 Graph-Compressed Dictionary Learning (GCDL)

In this paper, a graph compression method is proposed for application on large external dictionaries. Although, using a compact dictionary representation is not new, this method executes rapidly as a preprocessing step of SRC. Because SRC methods are *NP*-hard by nature, the homotopy method for the sparse optimization has been selected in this paper due to its time efficiency (Yang et al., 2010a).

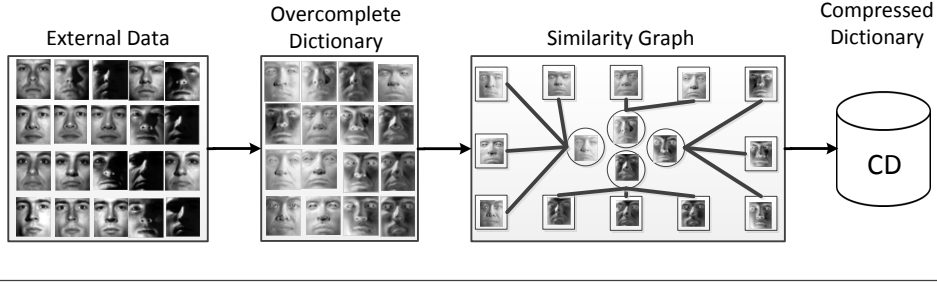
Figure 1 illustrates the proposed method. Assume that external data is collected a priori from non target individual over a network of surveillance cameras. It is assumed that the system can use a reference still face image, and faces captured in surveillance cameras for several non target persons. The first column represents the still image of its corresponding row. An overcomplete dictionary is constructed by calculating the difference between each image and it corresponding still image. A similarity graph is calculated based on overcomplete dictionary, where each image is a node in the graph and weighted edges present the similarity between nodes. In the similarity Graph block, the nodes that are marked with circles are atoms of the compressed dictionary. Finally, each probe sample is sparse linear combination of reference stills and compressed dictionary.

The edge weighted graph $G = (V, E, w)$ representing a set of n vertices that each vertices V_i is connected to the vertices V_j with an edge weighted and $E \subseteq V \times V$ is the set of edges. The weight $w(i, j)$ is obtained from the following formula.

$$w(i, j) = \exp\left(\frac{-\|ed(i) - ed(j)\|_2^2}{\sigma^2}\right) \quad (8)$$

where σ is a positive real number and it is bounded to $(0, 1]$, $ed(i)$ is a feature vector from external overcomplete dictionary ED and $\|\cdot\|_2$ is the Euclidean distance between the two values which gives dissimilarity between two considered elements. The graph G is complete and undirected with order of n that is the size of external overcomplete dictionary ED . Therefore

Design Phase:



Operational Phase:

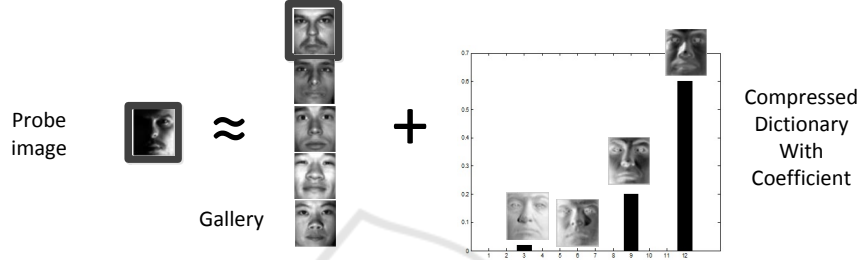


Figure 1: Schematic presentation of Graph Compressed Dictionary Learning (GCDL) method.

$w(i, j) = w(j, i)$ for all $(i, j) \in E$. A graph G is called a symmetric matrix G with order of n . Let $k \leq n$ be a constant representing that is the number of atoms or the order of compressed new graph C . The rate $\frac{k}{n}$ is regarded as the graph compression rate.

A many to one mapping $\psi: [n] \rightarrow [k]$ is needed between vertices of the original graph and compressed graph. The compressed graph must be determined to reduce the order of graph from n to k . To estimate the mapping function and compressed graph, a least squares approximation is applied on following minimizer by dropping a left-stochastic constrain to a real matrix X .

$$\begin{aligned} \min \quad & f(X, C) = \|G - X^T C X\|_2^2 \\ \text{s.t.} \quad & X \in \mathcal{S}, \quad C \in \mathbb{R}^{k \times k}. \end{aligned} \quad (9)$$

where

$$\begin{aligned} f(X, C) = & \sum_{(i,j) \in \{1,2,\dots,N\}} \sum_{k,h \in \{1,2,3,\dots,K\}} \delta_{(k,i) \neq (h,j)} X_{ki} X_{hj} \\ & \times (G_{ij} - C_{kh})^2 + \sum_{i \in \{1,2,\dots,N\}} \sum_{k \in \{1,2,3,\dots,K\}} X_{ki} (G_{ii} - C_{kk})^2. \end{aligned}$$

The optimization can be addressed as a EM method which alternates updates of the variable C and updates of the variable X . The minimization approach converges to a stationary point by updating a decrease of the objective function in every iteration.

Update rule for C .

The update rule for the unconstrained matrix C ,

$U_C(X)$, is obtained based on the first-order partial derivative of f with respect to C to zero ((Nourbakhsh et al., 2015), proof of Theorem for details).

Update rule for X .

$U_X(X, C)$ is a multiplicative rule for X that is in similar manner to the ones suggested in (Lee and Seung, 2001) for Non-negative Matrix Factorization (NMF).

We say that X is *Karush-Kuhn-Tucker (KKT)-point* for the following optimization if it satisfies the first-order necessary conditions for the local optimality (details are given in (Nourbakhsh et al., 2015)).

$$\begin{aligned} \min \quad & f_C(X) = f(X, C) \\ \text{s.t.} \quad & X \in \mathcal{J}_Z \end{aligned} \quad (10)$$

where $C \in \mathbb{R}^{k \times k}$, $Z \in \mathcal{S}$ and $\mathcal{J}_Z = \{X \in \mathcal{S} : (Z_{ki} = 0) \Rightarrow (X_{ki} = 0)\}$.

Algorithm 1 provides the summary of GCDL approach that works as follows. After calculating weighted graph from overcomplete dictionary (explained in Figure 1), the minimization optimization starts by a random selection of $X \in \mathcal{S}$ continued by repeatedly alternate between updating C and X with their respective update rules that are $U_C(X)$ and $U_X(X, C)$, until convergence. The stopping criteria is not when the distance between X s of two consecutive iterations is below a given threshold, and maximum number of iterations reaches a threshold. This procedure may converge to a local minima and it guarantees

a strict decrease of the objective until a KKT-point is reached. Finally, a discrete solution is obtained by projecting of binary left stochastic matrices by setting to 1 the element having highest value in each column of X and put to 0 the rest.

Although, the above compression method is not designed specifically for clustering, it converges good clustering that generate compact representation of input data. From this perspective, the mapping X encodes the clustering result. Then the representative vertices of each cluster based on the mapping X produce the dictionary atoms. The complexity of a matrix vector multiplication reduces from n^2 to $(k^2 + n)$.

Algorithm 1: Graph Compressed Dictionary Learning.

Input Data: Over-Complete Dictionary from External Data, $\leftarrow ED$

Output: Graph Compressed Dictionary, D_{GCDL}

Graph $G \leftarrow$ Calculate similarity matrix from ED

$X \leftarrow$ draw a random matrix from \mathcal{S} that is stochastic matrices

while stopping criterion is not met **do**

$C \leftarrow U_C(X)$ /* Update C */

$X \leftarrow U_X(X, C)$ /* Update X */

end while

Project X to binary left stochastic matrix

$D_{GCDL} \leftarrow$ Select the representative of each cluster based on the mapping matrix X

5 EXPERIMENTAL RESULTS

In this section the performance of the proposed GCDL method is compared to several state-of-the-art SRC¹ and DL methods: SRC (Wright et al., 2009), RSC (Yang et al., 2011b), ESRC (Deng et al., 2012), and $RADL$ (Wei and Wang, 2015). Baseline methods are categorized as methods without external dictionary (SRC and RSC) with external dictionary (such as ESRC and $RADL_{wo}$) and with both dictionary learning and classification like (SVDL and $RADL_wDL$). In addition, the time required to reconstruct compressed dictionary is also compared.

The results were obtained with images from the CAS-PEAL database (Gao et al., 2008) that is a large-scale Chinese face database which contains pose variations, expression, accessory, lighting and backgrounds. It contains facial captures from 1040 individuals (595 males and 445 females). For this experiment, we follow the protocol that has been discussed

¹<http://mml.citi.sinica.edu.tw/publications.html>

in the paper of (Wei and Wang, 2015). 100 subjects from the neutral category as gallery images D and their corresponding distorted images from accessory category were selected for testing. The accessory category contains 3 images with hats and 3 images with sunglasses so 600 images are collected for testing in total. The 60 subjects with 6 instances of its accessory category from the rest of 1040 individuals are chosen as external data to build dictionary ED . The pixel-based feature vector is obtained by downsampling the original grey-scale face images to 50×40 pixels.

1) For the first experiment the performance of GCDL is shown by varying the number of atoms (compression rate) with respect to other methods. The 60 individuals are used as external data with 6 instances for each. In our experiment, the size of external data is increased in each experiment by randomly selecting the data from 60 individuals that starts from 1 to 15 individuals for ESRC and $RADL_{wo}$. In a same manner, the external overcomplete dictionary is compressed from 360 elements, to have the same number of atom in each experiment.

Table 1 shows the accuracy of ESRC and $RADL_{wo}$ classification with different size of external data and compressed data. The average accuracy is shown for 10 experiments. Because the standard deviation is always negligible, it is not reported in the Table 1. We notice that by increasing the number of atoms, the performance increases in general. The overall performance for GCDL is generally higher than methods without external dictionary learning. The result shows that in low compression rate (equivalent to high number of atoms), accuracy is low compare to other methods. Since GCDL is based on clustering, the amount of information added to enhance SRC declines as the number of atoms grows. In another words, by increasing the number of atoms close to the total number of clusters, GCDL tends to partition data randomly without using structural information of data.

2) In the second experiment, the performance of GCDL is compared to some dictionary learning methods followed by classification algorithms such as $RADL_wDL$ and SVDL, then with K-SVD, MOD and SMRS are used for dictionary learning followed by $RADL_{wo}$ as classification. Results of ESRC and $RADL_{wo}$ are provided by applying whole external data without dictionary learning. Finally, results are also provided for SRC and RSC as a base line. Since these methods do not require external dictionary. The execution time of these methods are also compared. All codes are implemented in MATLAB, using a 3.40 GHz and 8 GB RAM computer.

Table 2 shows that the average execution time of constructing compressed dictionary by GCDL is

Table 1: Average classification accuracy of GCDL and references methods on CAS-PEAL data.

Methods with External Dictionary	Number of Atoms					
	6	12	18	30	60	90
ESRC	74.50%	74.50%	75.17%	75.83%	77.33%	78.33%
ESRC+GCDL	74.90%	75.57%	76.08%	76.35%	77.62%	77.85%
$RDAL_{wo}$	83.17 %	83.83%	84.33 %	84.00 %	85.90 %	86.83 %
$RDAL_{wo}$ +GCDL	83.95%	84.87%	85.53%	85.15%	85.97%	86.73%

Table 2: Average accuracy and reconstruction time of GCDL and references methods on CAS-PEAL data.

Methods with Dictionary Learning and Classification				
	Number of Atoms	Dictionary Size	Accuracy (%)	Time (Sec)
SVDL	19	2000×360	82.33 %	1607.87
$RADL_{wo}DL$	18	2000×360	85.67%	924.62
Methods with Dictionary Learning and $RADL_{wo}$ as Classification				
K-SVD	18	2000×360	84.96%	115.38
MOD	18	2000×360	85.17%	71.759
SMRS	17	2000×360	83.83%	3.28
Methods with Compression and $RADL_{wo}$ as Classification				
GCDL	18	2000×360	86.00%	0.87
Apply whole Raw Dictionary				
ESRC	360	2000×360	78.50%	169.69
$RADL_{wo}$	360	2000×360	87.00%	267.53
Methods without External Dictionary				
SRC			72.67%	
RSC			82.33%	

much lower than other methods. In addition, our method doesn't rely on parameter tuning like K-SVD, MOD and SMRS. And GCDL provides a comparable level of accuracy.

6 CONCLUSIONS

In this paper, the Graph Compression Dictionary Learning (GCDL) method based on matrix factorization is proposed to construct compact representation of overcomplete external data. The GCDL exploits the structural information on external dictionary to build compressed dictionary. It affects a trade-off between time complexity and accuracy. Experiment conducted with a high compression rate produces a better accuracy. Therefore we show that it is more robust to intra class variation compared to commonly used dictionary learning methods on literature. As a result, the proposed algorithm allows managing occlusion face images, or illumination and expression. Moreover, GCDL handles even one or few gallery images per individuals. The result on CAS-PEAL dataset show that GCDL has a better time efficiency for the construction of compact dictionary. It can be

employed to accelerate many SRC approaches, and the complexity of a matrix-vector multiplication can be significantly reduced.

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