DCT BASED REGION LOG-TIEDRANK COVARIANCE MATRICES FOR FACE RECOGNITION

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Introduction

I. Gabor-based Region Covariance Matrix (**GRCM**) has been demonstrated as a promising descriptor for face recognition.

- GRCM requires ***large number*** of filters to achieve satisfactory performance.
- Complex-valued Gabor filter requires ***double convolution operations*** for each filter that makes the computation more expensive.

II. Region Covariance Matrix **(RCM)** offers spatial information that is useful for recognition tasks

- ***Overly small*** RCM region renders ***poor covariance estimation***, which can affect the recognition performance drastically especially when both gallery and probe set have ***very different distributions***.

DCT as Filter Bank for Region Covariance Matrix

- **DCT Property as Filter Bank**
  - For real valued basis and input signal, convolution can be viewed as projecting overlapped (i.e. stride one) local signals onto a ***flipped basis.***
  - Both are equivalent for ***symmetric basis***, hence preserves the decorrelation characteristic.

$$X = \langle c, x \rangle = c^T x = \sum_{m=0}^{N-1} c[m]x[m]$$

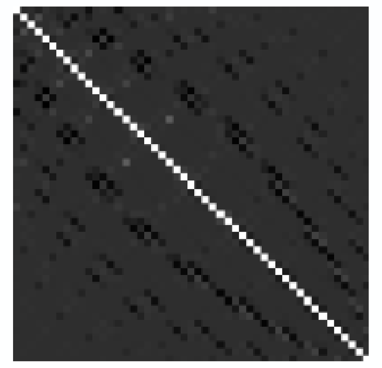
Inner Product

$$(f * x)[N] = \sum_{m=-M}^{M} f[N-m]x[m]$$

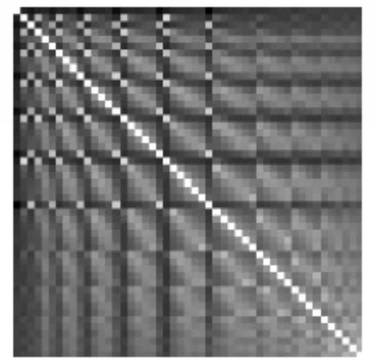
Convolution

- **DCT and RCM**
  - DCT an ***orthogonal transform***, transforms a signal into ***decorrelated spectrum***.
  - Decorrelated spectrum is ***not suitable*** for RCM construction.
  - ***Non-linear operation*** breaks the decorrelation among filter responses.

Correlation Matrix
49 7x7 DCT Basis
on a Face Image



Without Non-Linear Operation
Energy are concentrated only in diagonal entries

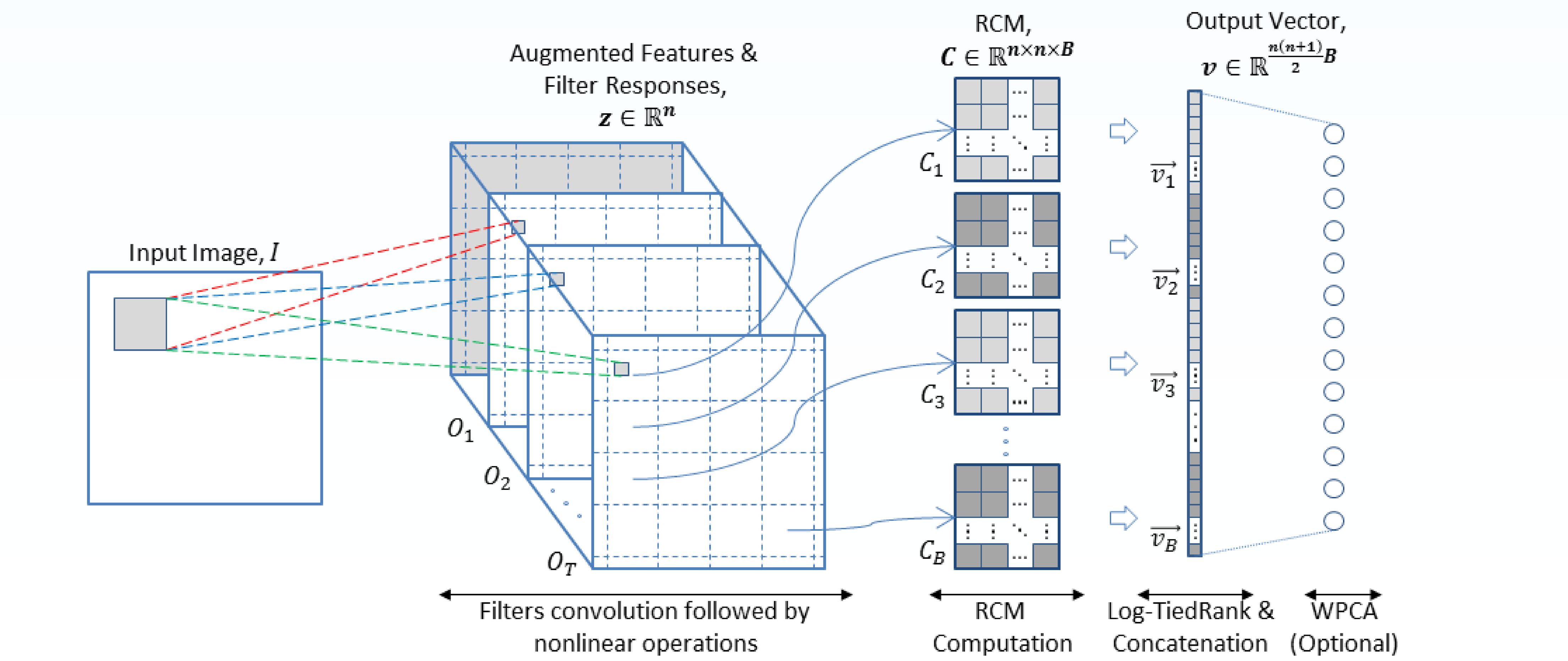


Absolute Operation
Energy spread to off diagonal entries

Region Log-TiedRank Covariance Matrix (RLTRCM)

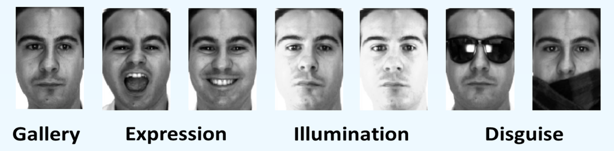
- **RCM Descriptor**
  - RCM is capable of implicitly encoding ***spatial information*** of local image regions with covariance matrix.
  - Smaller region gives ***better spatial precision***, but ***poorer covariance estimation***.
  - Covariance matrix is also known to be very ***sensitive to outliers***.
- **Tied Ranking**
  - Motivated by ***Spearman's rank correlation matrix (SRCM)*** ranking method.
  - Spearman's rank correlation matrix computes ***Pearson correlation*** among ***ranked variables***.
  - ***Eliminates disparity between variables***, more robust against undersampling and outliers.
- **Log-TiedRank Covariance Matrix (LTRCM)**
  - Non-singular covariance matrix is a Symmetric Positive Definite matrix that lies on ***Riemannian Manifold***.
  - Regulating SPD matrix is ***not trivial*** and replacing Covariance Matrix with SRCM ***computation expensive***.
  - **Construction**
    1. Embeds nonsingular covariance matrix into its ***tangent space*** with respect to ***origin*** (Identity Matrix) to form a symmetric matrix, S' which lies on ***vector space***.
    2. S' is then ***simplified*** and ***vectorized***.
    3. LTRCM vector is obtained by applying ***Tied Ranking*** on $\vec{S'} = [S'_{1,1}, \sqrt{2}S'_{1,2}, \sqrt{2}S'_{1,3}, \dots, \sqrt{2}S'_{n,n-2}, \sqrt{2}S'_{n,n-1}, S'_{n,n}]^T$

Block Diagram of Feature Extraction Pipeline



Experiment Results

A) Evaluation on Various Variations (AR Dataset)



Filter	Metric	Expression	Illumination	Occlusion	Average
Gabor	AIRM [2]	97.643	99.663	92.845	96.717
	Log-Euc	94.781	96.465	82.828	91.358
	Log-TR	**99.327**	**100**	**99.327**	**99.551**
DCT	AIRM	98.822	98.990	93.014	96.942
	Log-Euc	97.980	98.148	85.606	93.911
	Log-TR	98.485	99.832	98.317	98.878

B) Evaluation on Pose Variations (FERET Bc ~ Bh)

Filter	Metric	Bc	Bd	Be	Bf	Bg	Bh	Average
Gabor	AIRM [2]	50.5	94.0	99.0	99.0	88.5	48.0	79.83
	Log-Euc	45.0	86.0	97.5	98.0	83.5	43.5	75.58
	Log-TR	81.5	99.5	99.5	100	96.5	76.0	92.17
DCT	AIRM	61.0	94.5	99.5	99.5	94.5	70.0	86.50
	Log-Euc	52.5	89.0	99.0	99.5	91.5	62.5	82.33
	Log-TR	**94.5**	**100**	**100**	**100**	**99.0**	**89.0**	**97.08**

C) Comparison with other RCM Based methods (FERET Fb, Fc, Dup-I, Dup-II)

Method	Fb	Fc	Dup-I	Dup-II	Average
RCM [1]	85.19	27.84	44.04	29.06	46.53
Sigma Sets [19]	89.62	91.75	50.55	44.87	69.20
GRCM [2]	91.72	93.30	61.77	63.25	77.51
GWRCM [6]	91.63	93.30	62.19	64.10	77.81
DCT (AIRM)	93.72	95.36	68.56	70.94	82.15
DCT (Log-TR + WPCA)	**99.33**	**100**	**92.80**	**92.31**	**96.11**

Conclusion and Discussion

- From the experiment real-valued ***DCT*** with ***30 filters*** which requires less than ***half of the convolution*** operations outperforms complex-valued ***Gabor*** with ***40 filters*** in most cases.
- It is also shown that, ***DCT*** method is more robust against ***occlusions*** and ***pose changes***.
- With ***RLTRCM***, both Gabor and DCT methods shows ***significant boost*** over ***RCM*** especially when ***probe set*** is ***far deviated*** from ***gallery set*** (Pose Variations and Occlusions).
- Oppose to ***AIRM*** and ***Log-Euclidean*** which uses actual value representation, ***LTRCM*** that uses rank representation is ***insensitive to precision difference***, only rank order matters.