EXPERIMENTAL VALIDATION OF SUBJECT-SPECIFIC UNIQUENESS IN ESS[1] DOMAIN

In this section, we attempt to give an experimental validation for the existence of subject specific manifold in **ESS**. We implement this as follows: First we parameterize (using second degree polynomial fit) the multidimensional manifold for each subject in **ESS**. We consider this parameter matrix (one for each subject) to uniquely represent the manifold. Then we compute a Distance Matrix (T), where $T(i, j)$ is the distance (Euclidean norm) between the parameter vectors of i^{th} and j^{th} subjects. To exhibit the uniqueness, it suffices to show that the histogram ($Hist(T_N)$) of the normalized array T_N (where, array T_N is obtained by normalizing the $C \times C$ matrix T) should be left skewed for better separability between all possible pairs of subjects. $Hist(T_N)$, is assumed to be Gaussian in nature with a peak around the mean value. In the following, we explain the above conjuncture with mathematical formulation of the idea presented above.

Let,
C = No. of subjects.
M = No. of feature dimensions, for Fisherfaces [1] in our experiments.
Degree of polynomial fit = 2 (thus 3 parameters are necessary for each dimension).
PM_i is a $M \times 3$ parameter matrix for i^{th} subject, $i = 1, ..., C$.
T = $C \times C$ Norm Distance Matrix (symmetric) where,

$$T(i, j) = \|PM_i - PM_j\|_2 \tag{1}$$

Diagonal elements of T will be zero '0' as the parameter matrices (PM) for two identical (same) manifolds are being compared. We also normalize the entries in T in the range $[0, 1]$ to obtain T_N, using the formula:

$$T_N(i, j) = 1 - \frac{T(i, j)}{max(T)} \tag{2}$$

We expect the symmetric matrix T_N to have 1's along the diagonal and off-diagonal elements to be less than 1. The smaller is the maximum value (< 1) among all off-diagonal elements of T_N, (equivalent to the minimum among all off-diagonal elements of T) better is the uniqueness in representation of the manifold in **ESS** for discriminatively across subjects. To verify this we plot a set of T_N matrices for different databases, which is described in the following.

Norm Distance Matrices (T_N) for all the three datasets used in experiments- **IITM-SURV** (Gallery), **FERET** and **ORL**, are shown in Fig. 1. The color representation of these matrices show that the values of off-diagonal elements are far from the diagonal ($= 1$). To have exact qualitative estimate of this, we have used the histogram ($Hist(T_N)$) of the off-diagonal elements of T_N (see Fig. 2). These histograms exhibit a Gaussian-like distribution, having a peak around 0.5 or less. The maximum value of the off-diagonal elements in T_n is the first non-zero value to the left to 1 (strictly less than 1,since diagonal elements of T_N are all unity) in $Hist(T_N)$. These maximum values for the three databases are:

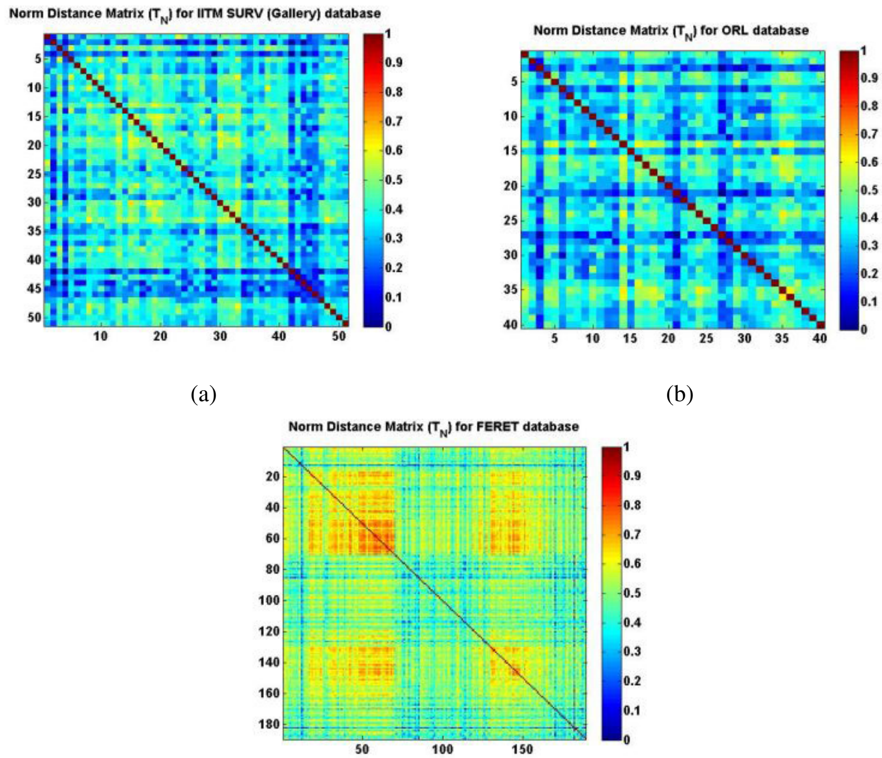
(i) **IITM-SURV** (gallery partition) - 0.63
(ii) **ORL** - 0.65
(iii) **FERET** - 0.8

Smaller these values better is the uniqueness across subjects in **ESS**. Larger values close to 1, would have revealed overlapping behavior of manifolds, and hance less separability. Also, observing the peaks of histograms we deduce that, most of the manifolds are parameterically different than the others by a distance of 50% from maximum similarity (i.e. value of 1 at the diagonal in T_N). Also note that, since T is symmetric (see Fig. 1) we have obtained the histograms in Fig. 2 using elements from upper triangular matrix of T_N. If the parameterized representation of the manifold is non-unique we would have obtained many off-diagonal elements of T_N closer to 1, i.e. the histogram would have been right skewed. Since this is not the case, this empirical study presented here reveals the unique nature of subject-specific manifolds in **ESS**, which has been exploited for **FR** under blurred imaging conditions.

REFERENCES

[1] P. N. Belhumeur, J. P. Hespanha, and D. J. Kriegman, "Eigenfaces vs. Fisherfaces: Recognition Using Class Specific Linear Projection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 19, no. 7, pp. 711–720, July 1997.

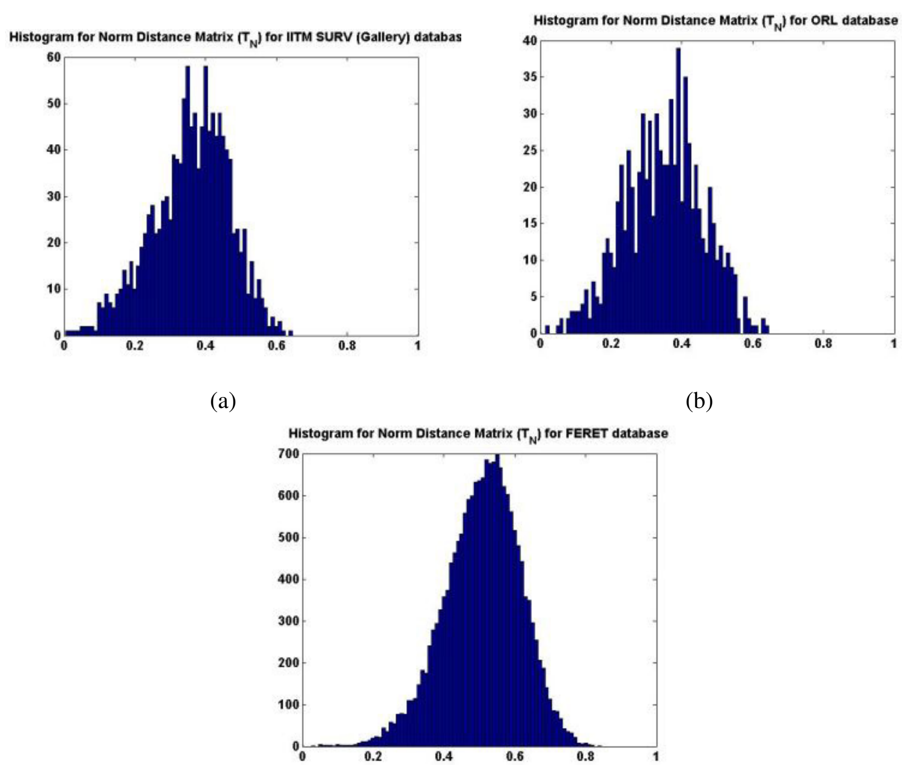
[1] Paper on ESS is under review



(a) (b)

(c)

Fig. 1. Norm Distance Matrices (T_N) for three datasets: (a) IITM-SURV (Gallery) (b) ORL and (c) FERET.



(a) (b)

(c)

Fig. 2. Histograms ($Hist(T_N)$) of Norm Distance Matrices (T_N) for three datasets: (a) IITM-SURV (Gallery) (b) ORL and (c) FERET.