6.1 SUMMARY OF THE THESIS

The problem encountered by a face recognition system when the database size is growing continuously, is studied in detail. A model that uses PCA approach is proposed for such large database. This model is then exhibited to an incremental training system called Incremental Principal Component Analysis (IPCA). The PCA is tested on Yale, FEI and GRIET databases. The principal components are extracted one from each eigenface, which are projected onto the orthogonal plane. The total number of selected principal components is equal to \((M-1)\), where \(M\) is the face space. With this approach, a linear relation is established between overall computational time and the number of faces in the face database. With this linear relation, an estimation of computational time is made possible in real world applications. An incremental training system is proposed with mean image and covariance matrix estimation. The recognition rate of incremental principal component analysis algorithm is tested on Yale, FEI and GRIET database.

The results from models in vogue are compared in terms of Root Mean Square (RMS) and Euclidean Distance. Taking minimal front view face dataset, a general evaluation is carried out. The impact
of pose variation is evaluated with help of parameters like rate of recognition and computational time.

As a new face is added to the existing database, the estimation of new mean and new covariance matrix is computed by the incremental training model. A continuous training process is carried out on the proposed incremental PCA. The database that is used for the evaluation of PCA, the same is used to measure the efficiency using IPCA. Finally, rate of recognition and overall computational time is estimated to measure the efficiency of IPCA with that of PCA. A multi-modal system aims at improving the performance when compared with 2D eigenfaces and 3D eigenfaces. From the observations, it is clearly seen that the performance of multi-modal PCA overcomes both 2D and 3D approaches.

6.2  **Salient features of the study PCA, IPCA and Multi–Modal**

**PCA:**

1. The proposed PCA (with the number of eigenvalues equal to the number of faces) is found to result in recognition efficiency of 99.8% when tested for 150 training images from Yale face database.

2. The same face database with some training set of 150 face images under the PCA is found to result with an overall computational time of 24.6 seconds.
3. The proposed PCA is found to result in recognition efficiency of 99.4% when tested for 2400 training images from FEI face database.

4. The same FEI face with training set of 2400 face images under the PCA is found to result with an overall computational time of 318.2 seconds.

5. The proposed PCA is tested on face database consists of 350 images representing various expressions and poses. The highest eigenvalue of 141.13 is observed for the cases 100 front views inclusions while this value is found to reach 246.32 if a combined front and side view face databases is considered.

6. The efficiency of front view face recognition is witnessed to be 88.4%. Whereas, for the combined database along with pose variations, it is found to be 93.9%. The deviation of efficiency between these two approaches is approximately 5%, which is marginal when database is combined.

7. The overall execution time, for the combined database is observed to be 38.7 seconds.

8. The computational time efficiency of present PCA for the database is estimated through the covariance matrix with and without the reduced dimensionality. The computational time with reduced dimensionality is found to be 30.8 seconds, whereas the computational time is found to increase by five times i.e., 149.6 for without covariance matrix reduction. Hence the reduction of dimensionality results in favorably.
**IPCA:**

1. Incremental PCA is evaluated with face database and FEI face database in the wake of earlier PCA and database of images added one by one. IPCA estimation parameter otherwise called as decay parameter ($\alpha$) is fixed at a cut of value of 0.9 after estimating the mean error and covariance matrix error.

2. The highest eigenvalue obtained from the combined set of Yale and GRIET databases (for 500 images) is found to be 563.24 after implementing IPCA.

3. The maximum recognition rate with IPCA (with 350 images) is observed as 96.4%, slightly more than 95.2% with PCA. Marginal derivation of recognition rate is attributed to the difference in the number of images considered. The fine, but weak tuning of performance is realized due to the inherent characteristics of PCA and the derived decay parameter ($\alpha$).

4. The efficiency of IPCA is evaluated in terms of overall computational time in comparison to PCA (considers a database of 3465 images of Yale, FEI and GRIET face database). The overall computation time found to be 48.8 seconds with IPCA, where as IPCA is rated meritorious with 20% time efficiency over PCA. Since overall computational time vary linearly with the number of considered faces in the present PCA and IPCA algorithms, it is possible to estimate, the amount of the required computational time for the specific cases burgeoning databases.
5. Since computational time seems to have linear with the number of faces in the proposed PCA and IPCA algorithms, it is possible to estimate the amount the time demand for large databases.

**Multi-Modal:**

Performance comparison of 2D, 3D and Multi-Modal face images from Yale database is computed. The result seems to be improving when 2D and 3D are combined.

### 6.3 Limitations of the present work

Inspite of its positive points, it has its own limitations, they are,

[1] The proposed model is tested using faces with pose variations. Much illumination changes, occlusion issues are not handled in the present work.

[2] A maximum number of 2800 faces are used for evaluation, where as in a real system the situation deals with large databases.

[3] Testing and training images are assumed with same dimensionality, where as the real world images differ in dimensionality. Similarly gray scale and static images are used for the present evaluation procedure that is far away from realistic environment.
Testing is considered as a separate activity that may be included as a part of training phase, which can convert the present system into an adaptive system.

6.4 Future scope of the work

The other aspects of the study are out of scope for the present study. However, some of the recommendation or suggestions for future study are given as follows:

1. The proposed PCA and IPCA algorithms don’t possess recognition accuracy of 100% due to its inherent disadvantage of selecting prominent but holistic features. This algorithm can be combined with any other technique like support vector machines, fisher faces etc., to achieve 100% recognition efficiency.

2. The proposed IPCA algorithm can be further extended as an adoption algorithm by considering the testing phase as a part of training. It is necessary to test the efficiency of the algorithm where in huge databases of the order of few thousands are carried out. Also efficiency needs to be enriched when using multi-modal database.

In this connection, before concluding, I wish to reiterate my thesis statement that, for the reduction of time and space complexity, an efficient incremental model could be designed and implemented in the real-world scenario.