FACE BASED MULTIMODAL BIOMETRICS
AUTHENTICATION SYSTEM

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in fulfillment of the requirements of the degree of

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This Thesis is dedicated to my eternal love
“LADDU GOPAL”.
CERTIFICATE

This is to certify that the thesis titled "**Face Based Multimodal Biometric Authentication System**" being submitted by Ms. **Mamta Bansal** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by her under my guidance and supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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FOREMOST, I PAY MY GRATITUDE TO MY GUIDE, PROF. M. HANMANDLU FOR PROVIDING ME THE CONSTANT ENCOURAGEMENT AND GUIDANCE AT EVERY STAGE OF MY RESEARCH. WITHOUT HIS STRONG SUPPORT AND SPIRITED MOTIVATION I COULD NOT HAVE ACHIEVED MY RESEARCH GOALS. I COULD NOT IMAGINE HAVING A BETTER SUPERVISOR THAN HIM FOR MY PH.D. STUDY. I EXTEND MY THANKS TO MY SRC MEMBERS, PROF. K. K. BISWAS, PROF. S. D. JOSHI, AND PROF. SUMANTRA DUTTA ROY FOR THEIR FRUITFUL SUGGESTIONS AND CRITICAL COMMENTS DURING MY RESEARCH PRESENTATION.

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ABSTRACT

Several multimodal biometric systems have been developed in the literature because of the growing security requirements under the unconstrained environmental conditions. The face based multimodal biometric system comprising IR face, Iris, Ear as its constituents is proposed in this thesis and it is designed to work under both the constrained and unconstrained environments where the conventional methods may fail. With view to make the system more efficient several new features and classifiers are developed and implemented on the proposed multimodal biometric system.

The concept of the information set is evolved while representing the uncertainty in a collection of attribute/property values by the Hanman-Anirban entropy function. Four features, viz., Effective Exponential Information source value (EEI), Effective Multi Quadratic Information source value (EMQDI), Energy Feature (EF) and Sigmoid Function (SF) are proposed based on the information sets. Next Principal Component Analysis (PCA) is converted into Local Principal Independent Components (LPIC) using the information set based features which can handle the unconstrained conditions better than PCA. A new classifier called Inner Product Classifier (IPC) is developed using the normed-error vectors which are obtained by applying t-norms on the error vectors between the training feature vectors and test feature vector. The inner product of the aggregate of the original training feature vectors and the normed error vector is considered as the criterion for determining the identity of a user. This is applied for the classification of the constrained and unconstrained ear databases.

The information set consisting of the information values can be modified by using a filtering function and transformed using the Hanman transform which is a higher form of information set.
In addition to the above four features, Hanman filter and Hanman transform features are also used for the representation of iris textures and tested on CASIA-Iris-V3-Lamp termed as DB1I, that contains eye images of 411 people.

Next, interactive features are developed from the above features in order to take care of the interaction between the features from adjacent windows. The effectiveness of these features are demonstrated on the IR face images with the help of two new classifiers called the Hanman classifier and the Weighted Hanman classifier that are developed by applying the Hanman-Anirban entropy function on the normed error vectors as used in IPC. The user identity corresponds to the least entropy value of the associated normed error vectors. The interactive features are evaluated using the proposed classifiers on IITD IR face (termed as DB1F) database with 1030 IR images from 103 users and on 9 other unconstrained IR databases containing occlusion, low resolution and noisy effects.

In order to handle the unconstrained conditions, a new entropy function having the provision to change the information source values unlike the Hanman-Anirban entropy function is formulated. The features from the previous chapters are modified in the light of the new entropy function. This entropy displays a peculiar characteristic that splits into two zones for a particular choice of its parameters not witnessed in other entropy functions. This new entropy function is utilized in changing the Hanman classifier to the Modified Hanman Classifier (MHC) that is shown to have better performance than that of SVM and KNN on IR face images. The new entropy based MHC is tested on the same databases of IR Face under the constrained and unconstrained conditions as used for evaluating the interactive features.

The new entropy features are applied to all three modalities of the proposed multimodal biometric system with each modality containing 100 users. To correct the erroneous scores,
Refines Score (RS) method is developed by utilizing the neighbourhood scores of the claimed samples. We have fused all three modalities under the unconstrained environment using the score level fusion alone and then improved the fusion by RS method. Here we have employed four fusion rules: sum, product, exponential sum, and tan-hyperbolic function out of which the product rule gives the best performance. The performance of the proposed multimodal biometric system is analyzed using the ROC plots.
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Table A.2 The recognition rates obtained using probabilistic entropy, possibilistic entropy, information values

Table A.3 The values of the fuzzifier and variance for comparison

Table A.4 Statistical Analysis of K-fold validation by using MQD feature
### ABBREVIATION

<table>
<thead>
<tr>
<th>Full name</th>
<th>Abbreviation</th>
<th>Symbol</th>
</tr>
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<tbody>
<tr>
<td>Features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information Set</td>
<td></td>
<td>$\mathcal{H}$</td>
</tr>
<tr>
<td>Effective Information Source value</td>
<td>EEI</td>
<td>$\bar{I}(k)$</td>
</tr>
<tr>
<td>Effective Exponential Information Source value</td>
<td>EEI</td>
<td>$\bar{I}^e(k)$</td>
</tr>
<tr>
<td>Effective Gaussian Information Source value</td>
<td>EGI</td>
<td>$\bar{I}^g(k)$</td>
</tr>
<tr>
<td>Effective Multi quadratic Information Source value</td>
<td>EMQDI</td>
<td>$\bar{I}^{MQD}(k)$</td>
</tr>
<tr>
<td>Effective Inverse multi-quadratic Information source value</td>
<td>EIMQDI</td>
<td>$\bar{I}^{invMQD}(k)$</td>
</tr>
<tr>
<td>Total Effective Gaussian Information</td>
<td>TEGI</td>
<td></td>
</tr>
<tr>
<td>Energy Feature</td>
<td>EF</td>
<td>$E(k)$</td>
</tr>
<tr>
<td>Sigmoid feature</td>
<td>SF</td>
<td>$S(k)$</td>
</tr>
<tr>
<td>Hanman Transform</td>
<td>HT</td>
<td>$H_T(l)$</td>
</tr>
<tr>
<td>Hanman Filter</td>
<td>HF</td>
<td>$H_{ij}(s)$</td>
</tr>
<tr>
<td>Local Principal Independent Component</td>
<td>LPIC</td>
<td></td>
</tr>
<tr>
<td>Exponential membership function</td>
<td>$\mu_{ij}^e$</td>
<td></td>
</tr>
<tr>
<td>Gaussian membership function</td>
<td>$\mu_{ij}^g$</td>
<td></td>
</tr>
<tr>
<td>Multiquadratic membership function</td>
<td>$\mu_{ij}^{MQD}$</td>
<td></td>
</tr>
<tr>
<td>Inverse Multiquadratic membership function</td>
<td>$\mu_{ij}^{invMQD}$</td>
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<tr>
<td>Conventional Features</td>
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</table>
Principal Component analysis PCA
Independent Component analysis ICA
Local binary patterns LBP
Shannon entropy $H_{Sh}$
Pal and Pal entropy $H_{PP}$
Tsallis entropy $H_{TS}$
Renyi entropy $H_{RN}$
Hanman-Anirban entropy $H$
Probability $p_{ij}$
Fuzzifier $f_{h(ref)}^2$

**Databases**

Perpinan Ear database DB1E
IIT Delhi Ear Database Version1 with 125 users DB2E
IIT Delhi Ear Database Version1 with 221 users DB3E
IITD Ear database DB4E
IITD IR Face database DB1F
CASIA-Iris-V3-Lamp DB1I
IIT Iris database DB2I

**Classifiers**

Euclidean classifier EC
Support Vector machine with linear kernel with degree 3 SVML
Support Vector machine with polynomial kernel with degree 3 SVMP
Inner Product Classifier IPC
<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
<td>Hanman Classifier</td>
<td>HC</td>
</tr>
<tr>
<td>Weighted Hanman classifier</td>
<td>WHC</td>
</tr>
<tr>
<td>Modified Hanman classifier</td>
<td>MHC</td>
</tr>
<tr>
<td>Refined Scores</td>
<td>RS</td>
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<tr>
<td>Euclidean Distance</td>
<td>ED</td>
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**Performance Evaluation**

<table>
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<tbody>
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<td>Receiver Operating Characteristic</td>
<td>ROC</td>
</tr>
<tr>
<td>False Acceptance rate</td>
<td>FAR</td>
</tr>
<tr>
<td>False Rejection rate</td>
<td>FRR</td>
</tr>
<tr>
<td>Genuine Acceptance rate</td>
<td>GAR</td>
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