FUZZY MOMENTS AS A MEASURE OF DIGITAL IMAGE MATCHING

A project report submitted by

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CERTIFICATE

This is to certify that the project entitled, **"Fuzzy moments as a measure of digital image matching"** submitted Kaushik Malakar, (Roll number 9925219), to the Indian Institute of Technology, Kharagpur, is a bonafide record of the work carried out by my supervision and guidance.

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To

My parents – Shri. M . S . Malakar and
Smt. S . Malakar

~ Kaushik Malakar

ACKNOWLEDGEMENTS

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- Outline of Work

INTRODUCTION

1.1 PREAMBLE

A new hierarchical scheme for digital investigation based on facial image, and incidental description has been outlined in this project. Fuzzy logic has been successfully used for matching of digital images. However, the methods of matching adopted in these works are computationally intensive and sensitive to rotation and size variation of images. Further, the existing matching techniques, which search a reference image among a set of images, often fail to identify the correct image in the presence of noise. Our present work attempts to overcome these limitations by a new approach using the concept of "FUZZY MOMENTS".

1.2 MOTIVATION

The available techniques of automated criminal investigation generally rely on fingerprints and facial imagery of suspects. Unfortunately classification of fingerprints and facial images by pixel-wise matching is tedious and the feature based schemes often lead to misclassification and hence improper matching. Moreover, facial imagery undergoes changes with aging and mood of the persons and thus matching of facial images in many occasions fails to identify the suspects.

The 'image matching' algorithm used here attempts to partially match the facial image of the suspects with known images. The main trick in this matching lies in 'Fuzzy Membership-Distance Product', which keeps track of the important features in human faces and their relative distances. The matching scheme has other advantages of size and rotational invariance. This means that the matching scheme is insensitive to variation of image sizes or their angular rotation on the facial image plane.

1.3 OBJECTIVE

Our main objective in this project was to develop a user friendly digital investigation system for matching a gray-scale image among a given database of many images.

1.4 OUTLINE OF WORK

Here we have used the concept for matching of digital images by estimating and comparing the fuzzy moments w.r.t. each partitioned block of images. The proposed method is free from size and rotational variance and requires insignificantly small time for the matching process. The smaller the size of the partitioned block in the image, the higher is the computational time for matching. The choice of the size of each partition block, therefore, is a pertinent decisive factor in connection with the process of matching.

The fuzzy membership functions used in this context have been chosen intuitively. There exists ample scope of selecting appropriate membership functions in a judicious manner. Selection of membership functions that cause the least error in the process of matching is yet to be identified.

- ❋ **Introduction**
- ❋ **Image Features & their Membership distribution**
- ❋ **Fuzzy membership distribution**
- ❋ **Fuzzy Product Rule**
- ❋ **Fuzzy Moment descriptors**
- ❋ **Implementation**
  - **Algorithm**
  - **Code**

IMAGE MATCHING

A.I.

ARTIFICIAL INTELLIGENCE

2.1 INTRODUCTION

Fuzzy logic has been successfully used for matching of digital images. However, the methods of matching adopted in these works are computationally intensive and sensitive to rotation and size variation of images. Further, the existing matching techniques, which search a reference image among a set of images, often fail to identify the correct image in the presence of noise. Our present work attempts to overcome these limitations by a new approach using the concept of "FUZZY MOMENTS".

In this work, a gray image has been partitioned into n^2 non-overlapped blocks of equal dimensions. Blocks containing regions of three possible characteristics, namely, 'edge', 'shade', and 'mixed-range', are then identified and the sub-classes of edges based on their slopes in a given block are also estimated. The degree of membership of a given block to contain edges of typical sub-class, shades and mixed-range is measured subsequently with the help of a few pre-estimated image parameters like average gradient, variance and difference of maximum and minimum of gradients. Fuzzy moments, which informally mean the membership-distance product of a block b[i,w] with respect to a block b[j,k], is computed for all $1 \le i, w, j, k \le n$. A feature called 'sum of fuzzy moments' that keep track of the features and their relative distances is used a image descriptors. The descriptors of an image are compared subsequently with the same ones of other images. We used an Euclidean distance measure to determine the distance between the image descriptors of two images. To find the best matched image among a set of images, we compute the Euclidean distance of the image descriptors of the reference image with all the available images. The image with the smallest Euclidean distance is considered to be the 'best matched image'.

2.2 Image Features and Their Membership Distributions

A set of image features such as edge, shade and mixed-range and their membership distribution are defined here :-

An **EDGE** is a contour of pixels of large gradient with respect to its neighbours in an image.

A **SHADE** is a region over an image with a small or no variation of gray levels.

A **MIXED-RANGE** is a region excluding edges and shades on a given image.

A linear edge segment that makes an angle α with respect to a well defined line (generally the horizontal axis) on the image is said to be an **EDGE WITH EDGE-ANGLE α**. In this chapter we consider edges with edge-angle –45°,0°,45° and 90° .

FUZZY MEMBERSHIP DISTRIBUTION $\mu_Y(X)$ denotes the degree of membership of a variable X to belong to Y, where Y is a subset of a universal set U.

The **GRADIENT[5]** at a pixel (x,y) in an image here is estimated by taking the square root of the sum of difference of gray levels of the neighbouring pixels with respect to pixel (x,y).

The **GRADIENT DIFFERENCE (G_{diff})** within a partitioned block is defined as the difference of maximum and minimum values in that block.

The **GRADIENT AVERAGE (G_{avg})** within a block is defined as the average of the gradient of all pixels within that block.

The **VARIENCE (σ^2) OF GRADIENT** is defined as the arithmetic mean of square of deviation from mean. It is expressed as

$$\sigma^2 = \sum(G-G_{avg})^2 P(G)$$

where G denotes the gradient value at pixel, and P(G) represents the probability of the particular gradient G in that block.

2.3 Fuzzy Membership Distributions

Once features of the partitioned blocks in an image are estimated following the previous definitions, the same features may be used for the estimation of membership value of a block containing edge, shade and mixed-range.

For these estimations we, however, require the membership distribution curves, describing the degree of a block containing edge, shade and mixed-range. These distributions have been assumed intuitively by common sense reasoning.

2.4 Fuzzy Production Rules

A fuzzy production rule is an IF-THEN relationship representing a piece of knowledge in a given problem domain. For the estimation of fuzzy memberships for a block b[j,k] to contain, say, edge, we need to obtain the composite membership value fro their individual parametric values. The IF-THEN rules represent logical mapping functions from the individual parametric memberships tote composite membership of a block containing edge. The production rule PR1 is a typical example of the above concept.

PR1 : IF ($G_{avg} > 0.142$) AND
($G_{diff} > 0.707$) AND
($\sigma^2 \cong 1.0$)
THEN(the block contain edges).

Let us assume that the G_{avg}, G_{diff} and σ^2 for a given partitioned block have found to be 0149, 0.8 and 0.9 respectively. The μ_{edge} ($b_{j,k}$) now can be estimated first by obtaining the membership values μ_{edge} ($b_{j,k}$) w.r.t. G_{avg}, G_{diff} and σ^2 respectively by consulting the membership curves and then by applying the fuzzy AND (minimum) operator over these membership values. The single valued membership, thus obtained, describes the degree of membership of the block b[j,k] to contain edge. For edges with edge-angle α, we use the membership curves and obtain the composite membership of a block containing edge with edge-angle α by ANDing the membership of a block containing an edge with the membership of its having an edge angle α.

The composite degree of membership of a block containing shade and mixed-range has been computed similarly with the help of more production rules, the format of which are similar to that of PR1.

2.5 Fuzzy Moment Descriptors

Here we define fuzzy moments and evaluate image descriptors based on those moments.

FUZZY SHADE MOMENT $[M^{j,k}_{i,w}]_{shade}$ is estimated by taking the product of the membership value $\mu_{shade}(b_{j,k})$ (of containing shade in the block b[j,k] and normalized Euclidean distance $d_{i\,w,\,j\,k}$ of the block b[j,k] w.r.t. b[I,w]. Formally

$$[M^{j,k}_{i,w}]_{shade} = d_{i\,w,\,j\,k} \times \mu_{shade}(b_{j,k})$$

Fuzzy mixed-range and edge moments with edge-angle α are also estimated only by replacing the term shade by appropriate features.

The **FUZZY SUM OF MOMENTS (FSM),** for shade $S_{i,w}$, w.r.t. block b[i,w] is defined as the sum of shade moments of the blocks where shade membership is the highest among all other membership values.

$$S_{i,w} = \sum_{\exists jk} d_{i,w,j,k} \times \mu_{shade}(b_{j,k})$$

where $\mu_{shade}(b_{j,k}) \geq \mu_x(b_{j,k})$,$x \in$ set of features.

The FSM of the other features can be defined analogously following the above expression.

After the estimation of fuzzy membership values for edges with edge-angle α ,shades and mixed-range, the predominant membership value for each block and the predominant feature are saved. The FSMs w.r.t. the predominant features are evaluated for each block in the image. For each of six predominant feature (shade, mixed-range and edges with edge-angle -45°, 0°, 45°, 90°) we thus have six sets of FSMs . Each set of FSM (for example the FSM for shade) is stored in an one dimensional array and is sorted in a descending order. These sorted vectors are used as descriptors for the image.

For matching a reference image with a set of known images, one has to estimate the image descriptors for the known images. Normally the image descriptors for a known set of images are evaluated and saved prior to the matching process. The descriptors for the reference image, however, are evaluated in real time when the matching process is involved. The time required for estimation of the descriptors, therefore, is to be reduced to an extent, whatever possible, to keep the matching process executable in real time.

The matching of images requires estimation of Euclidean Distance between the reference image w.r.t. all other known images. The measure of the distance between descriptors of two images is evident from definition.

The **EUCLIDEAN DISTANCE,** $[E_{i,j}]_k$ between the corresponding two k^{th} sorted FSM descriptor vectors V_i and V_j of two images i and j of respective dimensions (n×1) and (m×1) is estimated first by ignoring the last (n-m) elements of the first array, where n>m and then taking the sum of square of the elemental differences of the second array w.r.t. the modified first array having m elements.

It may be added that the elements of the second and the modified first array are necessarily non-zero.

The measure of distance between two images, hereafter called **IMAGE DISTANCE**, is estimated by taking exhaustively the Euclidean Distance between each of the two similar descriptor vectors of the two images and then by taking the weighted sum of these Euclidean Distances.

The distance $D_{r,y}$ between a reference image r and a image y is denoted as

$$D_{r,y} = \sum \beta_k \times [E_{i,j}]_k$$

Where the suffix i and j in $[E_{i,j}]_k$ corresponds to the set of vectors V_i for image r and V_j for image y, for $1 \le i, j \le 6$.

For identifying the best matched image (among the set of known images) w.r.t. the reference image, one has to estimate the image distance $D_{r,y}$ where $y \in$ the set of known images and r denotes the reference image. The image q for which the image distance $D_{r,q}$ is the least among all such image distances is considered the **BEST MATCHED IMAGE.**

2.6.1 IMAGE MATCHING ALGORITHM:-

The major steps of the image matching procedure is given below :-

```
Procedure Image-matching(IM1 ,IM2 , . . . ,IMm+1)
// IM1 = reference image
Begin
    For   p=1 to m+1 do begin
          Partition IMp into non-overlapping blocks of (n×n)pixels;
          //estimation of parameters and membership values
          For block=1 to n^2 do begin
               Find-parameters (f(e, y), Gavg , Gdiff , σ^2);
               Find-membership(Gavg , Gdiff , σ^2,  μedge(block) ,
                               μedge(block) , μshade(block) , μMR(block));
          End For ;
          //Sum of moment computation
          For i =1 to n do begin
               For w =1 to n do begin
                    k = n × (I-1) + w;
                    //mapping from 2-d with indices (i,w) to 1-d with
                    //index k
                    Find – moment – sum (Si,w , MRi,w , E0i,w , EP45i,w ,
```

$E45_{i,w}$, $E90_{i,w}$);

$S_p[k] = S_{i,w}$;

$E45_p[k] = E45_{i,w}$;

$EP45_p[k] = EP45_{i,w}$;

$E0_p[k] = E0_{i,w}$;

$E90_p[k] = E90_{i,w}$;

$MR_p[k] = MR_{i,w}$;

End For ;

End For ;

Sort (S_p , MR_p , $E45_p$, $EP45_p$, $E0_p$, $E90_p$);

//This procedure sorts arrays S_p , MR_p etc. into descending

//order and places the resulting vector into corresponding arrays

//Image identification from Euclidean distance

For p = 2 to (m+1) **do begin**

//p=an index to represent image

$Euclid_p = 0$;

$Euclid_l = 0$;

For $X_p \in \{ S_p , MR_p , E45_p , EP45_p , E0_p , E90_p \}$ and

$X_1 \in \{ S_1 , MR_1 , E45_1 , EP45_1 , E0_1 , E90_1 \}$

in order **do begin**

Find – distance (X_p , x_1 , dx_p) ;

$Euclid_p = [Euclid_p + d^2x_p]^{1/2}$;

End For ;

If $Euclid_p > Euclid_{p-1}$ then

image = p-1 ;

Else

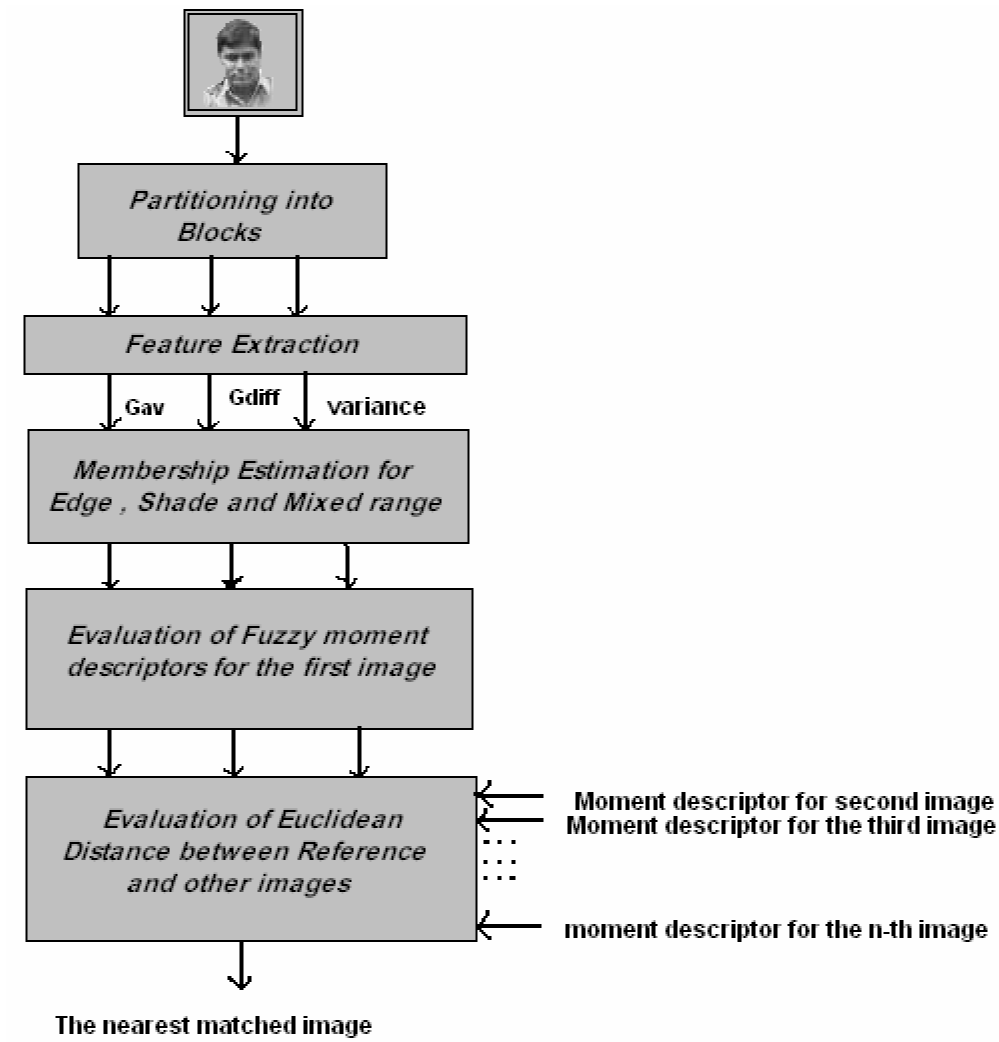
image = p ;

End For ;

End For ;

End.

An outline of the image matching scheme :-



CONCLUSION

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Artificial Intelligence (AI) techniques are now being used by the practising engineer to solve a whole range of hitherto intractable problems. This is an application of the Artificial Intelligence in a practical system for digital investigation. It receives two different types of inputs, namely, facial images and incidental descriptions about the persons and determines the best matched with the available information. The technique used are insensitive to small noises. The image matching scheme is very rugged as it records the membership-distance product, which does not change much for small gaussian noise. We keep a rich database using which the information about each person present in the database can be retrieved at any instant of time.

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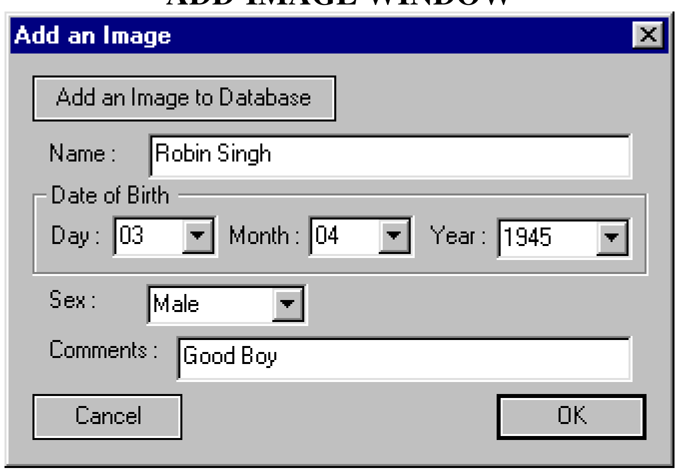
* Results

APPENDIX

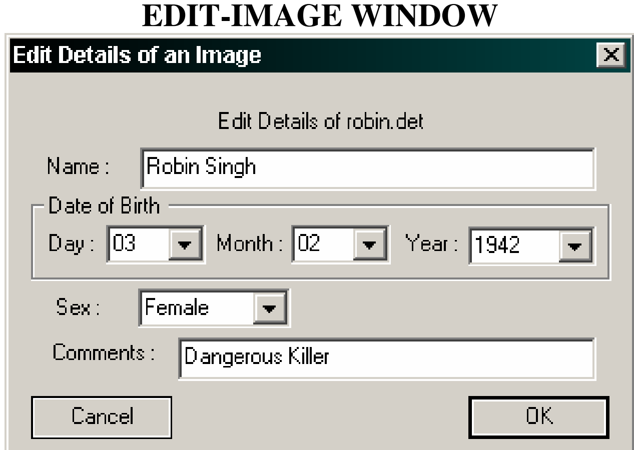
R E S U L T S

MAIN WINDOW

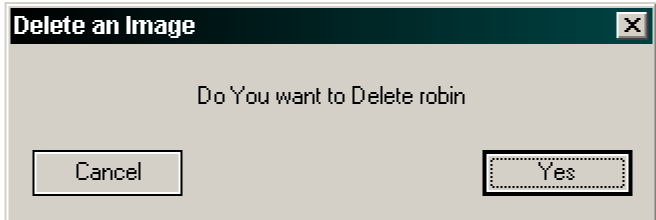
ADD-IMAGE WINDOW



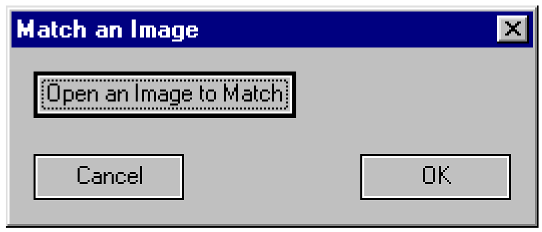
EDIT-IMAGE WINDOW



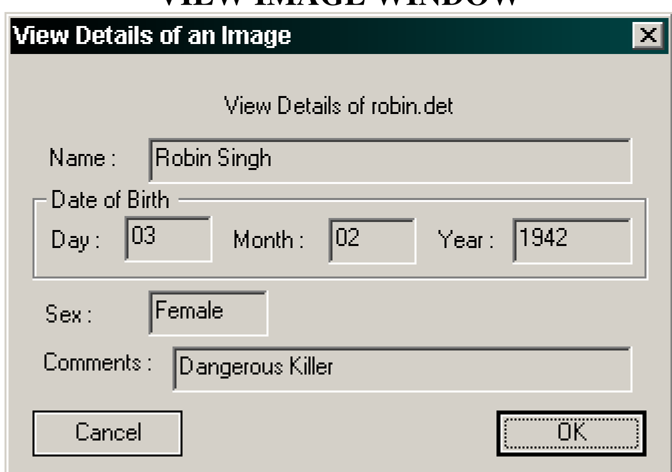
DELETE-IMAGE WINDOW



MATCH-IMAGE WINDOW



VIEW IMAGE WINDOW



FIND IMAGE WINDOW