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Graphics & Vision

Highlights

- Improved Image Denoising
- Diagonal and Matrix Features
- Exerting Moment Algorithms
- Restoration of Blurred Images

Discovering Thoughts, Inventing Future

VOLUME 16 ISSUE 1 VERSION 1.0

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Graphics & Vision

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Two Degree-of-Freedom Camera Support System

By Md. Nasir Uddin, MM Rashid, M Parvez, MM Sultan, SZ Ahmed, NA Nithe, JI Rony & MT Rahman

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Abstract- A surveillance camera is used to observer and record the surroundings. There are many types of existing surveillance camera and each of them has their own specifications made to suit their respective purposes. For example, there are fixed, 1-degree-of- freedom (DOF) and2-DOF cameras. As for a moving camera, it is essential for it to be able to move freely so that it can capture the target object in awider range. The camera also should be able to be controlled wirelessly to give a better practicality to the user. Based on the specifications, this project is constructed to overcome these problems. A 2-DOF camera support system is to be created which can be controlled wirelessly via Bluetooth. The support will e made with two motors that can pan and tilt the camera. The user will need to download an application which has o screen control into their gadgets and this can be connected to the Arduino which controls the motors. The Arduino will process the command from the user and will move the right motor to execute the command. This project will help the user to control the surveillance camera from a distance wirelessly and have at least a 360° pan view and 90° tilt view.

GJCST-F Classification: I.4.1

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Two Degree-of-Freedom Camera Support System

Md. Nasir Uddin [α], MM Rashid [σ], M Parvez [ρ], MM Sultan [Ѡ], SZ Ahmed [¥], NA Nithe [§], JI Rony [χ] & MT Rahman [ν]

Abstract- A surveillance camera is used to observer and record the surroundings. There are many types of existing surveillance camera and each of them has their own specifications made to suit their respective purposes. For example, there are fixed, 1-degree-of- freedom (DOF) and2-DOF cameras. As for a moving camera, it is essential for it to be able to move freely so that it can capture the target object in awider range. The camera also should be able to be controlled wirelessly to give a better practicality to the user. Based on the specifications, this project is constructed to overcome these problems. A 2-DOF camera support system is to be created which can be controlled wirelessly via Bluetooth. The support will e made with two motors that can pan and tilt the camera. The user will need to download an application which has o screen control into their gadgets and this can be connected to the Arduino which controls the motors. The Arduino will process the command from the user and will move the right motor to execute the command. This project will help the user to control the surveillance camera from a distance wirelessly and have at least a 360° pan view and 90° tilt view.

Chapter 1

I. Introduction

a) Background Studies

Surveillance brings the meaning of the observation of the actions, behavior, or other changing information, typically of individuals to influence, direct, manage or protect them. By using a surveillance camera, the surroundings can be observed, recorded and re- watched for future references.

There are many types of surveillance camera available in the market. Each of them is made to serve different purposes. For example, a bullet surveillance camera is usually placed indoors and it is mounted on the wall. The view is fixed and it is uncontrollable. Besides that, There are widely used for wide-area surveillance environment. Some of them are already programmed to move on their own, and there are ones which are controllable by the user.

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Usually the security cameras are controlled using the control panel from the control room. This project will ease the user as it will be interfaced with the Android application so the user can control it without having to bring a remote control.

b) Problem Statement

A moving camera support will offer many advantages compared to a static one. It will allow the user to point a surveillance camera to the target object better. Another potential usage will also be an automatic tracking of a moving object. To achieve this, a 2-DOF camera support is required and will be designed and implement ted. The camera support should be controllable wirelessly to improve its usefulness for the users.

c) Research Objectives

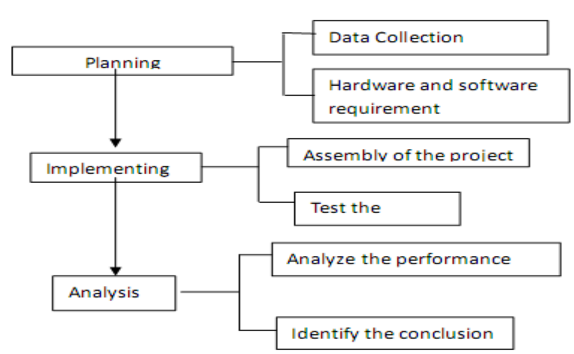
The purpose of this project is to design a 2-DOF support that can hold a video camera. The movement of the support is expected to be controlled via a wirelees communication, from and android device.

The core objectives of this project are:

1. To design a 2-degree-of-freedom camera support (Yaw and Pitch)
2. To design the controllers.
3. To design the wireless communication hardware and software.
4. To implement and test the design.

d) Research Methodology

Methodology is the theoretical arguments that researchers use to vindicate their research methods and project. Research methodology is the procedure of conducting research in order to achieve the aim of the project. These are the methodologies that have been lain out for this project. There are three parts for the process, which is planning, implementing and analysis.



For planning the first one is the data collection or literature review. A study of past projects that can help with the understanding of the research is done. From these studies, new ideas can be implemented to the project with references from existing ones. For this part, the different types and designs for the mount has been studied. Next is to select the components that are most suitable to be used in the project. The components are chosen based on their materials and the calculations made. For the software requirements, a couple of softwares are compared and most suitable is to be implemented.

After that, the hardware and software parts are integrated and the project is tested. Based on the data collected from the test, the performance of the project will be further analyzed to improve it until all the objectives are achieved. Fanally, the conclusion of the project is to be identified and a complete paperwork is prepared.

Chapter 2

II. Literature Review

a) Introduction

The aim of this project is to construct a 2 degree of freedom camera support system that can pan 360° and tilt 9°. This system is to be controlled from an Android application in the phone via Bluetooth. With this, the surveillance camera can be controlled wirelessly and ease the user.

b) Fixed surveillance Camera[1]

A fixed surveillance camera only points to one direction, which makes them very suitable for monitoring very specific area of interest. Besides that, they are used when it is beneficial to install them in clearly visible locations. Therefore, fixed surveillance cameras are quite effective not only to capture footages of suspicious activity, but also for deterring criminals and vandal from doing their acts to begin with. The direction of the camera is set during the installation phase. To cater to a wide variety of surveillance needs, they commonly accept interchangeable lenses and housings.

c) Two-stage Motor-on-Motor (MOM) Design[2]

In this design, the first motor will be placed at the bottom of the support so it can turn the mechanism through one degree of freedom, that is pan or yaw direction. Then the other motor is placed on top of the first motor and moves the mechanism in the pitch or tilt direction. It must be powerful enough to move the camera. Due to the placement of the motors in this design, the first motor is usually more powerful than the second one. It is because it needs to support the weight of the second motor together with the camera.

d) Parallel Linkage Design [3]

Two linear stepper motors are used in this design. It is also called a Platform Pantilt. The platform is moved by lowering and raising two shafts attached to linear stepper motors that, along with a third fixed shaft, are attached to the platform. Single and double universal joints are used to be attached to the to the shafts. This design is quite alike to the six-degree-of – freedom Steward plat form. This design is good in a way, but it has a limited precision and because it uses stepper motors, it is hard to construct this device in a small scale.

e) Motor [4]

A brushless DC motor runs from a DC power source but it does not have commutators and brushes. A brushless DC motor is more efficient, reliable, have low electrical noise and good speed control as compared to a brushed DC motor. While the key advantage to it is it has no brushed or commutaotr to wear out producing a much higher speed and lower maintenance.

On the other hand, a stepper motor does not rotate continuously like a conventional DC motor but it moves according to its step angle, with the angle of each rotational movement or step relies to the number of stator poles and rotor teeth that the stepper motor has.

For this project, the brushless DC motor is believed to be the best motor to be used.

f) Bluetooth

Bluetooth is wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz[4] from fixed and mobile devices, and building personal area networks (PANs). It was invented by Ericsson in 1994 and was regarded as a wireless substitute to RS-232 data cables. It can be connected to a number of devices, overcoming problems of synchronization.

Bluetooth is a standard wire–replacement communications protocol primary designed for low-power consumption, with a short range based on low-cost transceiver microchips in each device. To connect to Bluetooth, the devices do not have to be in visual line of sight of each other as it uses a radio communication system. But then, a quasi-optical wireless path must be viable. The effective range of Bluetooth is affected by the propagation conditions, material coverage, battery conditions variations, production sample and antenna configurations. The Bluetooth Core Specification mandates a range of not less than 10 meters, but there is no upper bound on actual range. Manufacturer's implementations can be tuned to provide the range needed for each case.

g) Wireless Local Area Network

A wireless local network (WLAN) is a wireless computer network that connects devices by a wireless distribution method within a bounded area. This allows the user to move around within the area without being disconnected to the network.

A peer-to-peer network permits the wireless devices to directly communicate with one another. They can discover and communicate directly without involving a central access point as long as they are within each other's range. This method is usually used by two devices so they can connect to each other from a network. This can only happen to devices that are in close proximity.

h) Android [5]

Android is a mobile operating system (OS) based on the Linux Kernel and currently developed by Google. With a user interface based on direct manipulation, Android is designed primarily for touch screen mobile devices such as smart phones and tablet computers, with specialized user interfaces for televisions (Android T), cars (Android Auto), and wrist watches (Android Wear). The OS uses touch inputs that loosely correspond to real-world actions, like swiping, tapping, pinching, and reverse pinching to manipulate on-screen objects, and a virtual keyboard. Despite being primarily designed for touch screen input, it has also been used in game consoles, digital cameras, regular PCs and other electronics.

Chapter 3

III. System Analysis and Methodology

a) Introduction

This chapter will discuss the integrated system of the surveillance camera support system and also the ways to implement them. This project can be breakdown into two parts, which is the hardware part and software part.

b) Project Overview

The system is divided into hardware design and software design. The hardware design has 3 further breakdowns which are electrical design, mechanical design and bill of materials. The materials and hardware are decided upon after comparing with different options and the most suitable is selected so that the project will work at optimum performance.

Figure 3.1 shows the overall flow of the system. The inputs come from the android device and then through the Bluetooth module, the signals is delivered to the Ardui no for further processing. Next, the Arduino sends signals to respective motors for them to move according to the input from the user.

c) Electrical Design

The systems electrical design and component selections will be further discussed.

d) Component Selection

From the literature review, these components is deemed the most suitable to be used in this project for it to be working successfully. There are few factors that came into consideration for the components to be chosen such as size, durability, maintenance and price.

No	Name of omponents	Quantity
1.	Arduino UNO	1
2.	20 rpm Motor	1
3.	30 rpm Motor	1
4.	Arduino Motor Shield	1
5.	Bluetooth Module	1

e) Arduino UNO

The Arduino Uno is a microcontroller board on the A Tmega 328 (datasheet). It is consist of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a power jack, a USB connection, an ICSP header and a reset button. It has everything required to support the microcontroller; just connect it to a computer with a USB cable or power it with an AC-to-AC adapter or battery to get started. The Uno is different from all previous boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmegal16U2(Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Microcontroller	ATmega328
Operating Voltage	5V
Input voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Analog Input Pins	6
DC Current per I/O Pin	40mA
DC Currentfor 3.3 V Pin	50mA
Digital I/O Pin	14 (of which 6 provide PWM output)
Flash Memory	32KB (ATmega328) of which 0.5 KB used by boot-loader
SRAM	2KB (ATmega328)
EEPROM	1KB (ATmega328)

Calculations of the torque have been made prior to the selections of the DC motors.

Let the mass of the camera= 3N, width =0.021m, height= 0.05m

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Based on the torques calculated, the 20 rpm motor is selected as it can handle the motor torque calculated.

These are the specifications of the motor:

Operating Range: 3-12VDC Output Power: 1.1Watt

Torque@Max Efficiency: 0.27N.m (12V)

Torque @ stall: 1.306N.m.@12VDC

Stall current: 0.5A @ 12VDC

(6mm) Diameter Shaft

No load current: 45mA
No load current@ Max Efficiency: 95mA (12V)
No load speed: 20 RPM
No load speed @ Max Efficiency: 15.9 RPM
Gear ratio: 150:1
Motor size:1.30" Dia. x 1.015"L
Gear size: 1.45"Dia. x .985"L
Shaft size: 6mm (0.236") Dia. x 0.715"L
Weight: 0.2813 1bs. (4.5 oz)

f) Motor Driver

Logic Control Voltage: 5V (From Arduino)
Motor Driven Voltage: 6.5~12v (VIN Power Supply), 4.8~35V (External Power Source)
2 way motor drive
Logic supply current Iss: ≤36mA
Motor Driven current Io: ≤2A
Maximum power consumption: 25W (T=75°C)
Up to 2A current each way
Pin 4, 5,6,7 are used to drive two DC motor
Support PWM speed control
Support PLL advance speed control
Size: 55x55mm

g) Bluetooth Module

Supply voltage: 3-3V DC
Transmitter output power: 18dBm
Receiver sensitivity: -86dBm
Mounting: SMD
Standard: 2.0 EDR
Bluetooth class: 1
Operating temperature: -40…85°C
Dimensions: 28.2 x 15 x 2.8mm Interface:
PCM
UART
USB
Additional information
Gross weight: 3.88 g
Collective package [pcs]: 400

h) Mechanical Design

The mechanical design is modeled with Solid works software. The drawings are attached in the appendices.

i) Bills of Materials (BOM)

The total cost of the development of the surveillance camera support system is as below:

Table 3.3 : Bills of Materials

Parts	Quantity	Price (RM)
Arduino	1	117.00
20 rpm DC Gear Motor	2	90.00
Motor Shield	1	43.00
Bluetooth Module	1	42.00
1000mmx60mmx30mm Mild Steel Plate	1	25.00
Gear	2	20.00
TOTAL COST		RM 427.00

Chapter 4

IV. Conclusion

a) Achievement of objectives

Overall most of them objectives for this FYP 1 have been achieved. The 2-DOF camera support system has been designed. The final mechanical and electrical components have been selected from various selections based on the calculations results, suitability and cost. The wireless connection is decided to be via Bluetooth connected to the Android device. The support system is expected to move smoothly and comply with the specifications set.

b) Limitation and challenges

The limitation of this project is to make the size smaller. It is because the components involved are quite big in size. The design that has been decided is the smallest one while taking into account the costs involved.

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Exerting Moment Algorithms for Restoration of Blurred Images

By K. Bhima & Dr. A Jagan
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Abstract- In this paper presents the restoration of blurred images which gets degraded due to diverse atmospheric and environmental conditions, so it is essential to restore the original image. The research outcomes exhibit the major identified bottleneck for restoration is to deal with the blurred image as an input to imaging agent employing various methodologies ranging from principle component analysis to momentary algorithms and also a set of attempts are been executed in image restoration using various algorithms. However the precise results are not been proposed and demonstrated in the comparable researches. Also detail understanding for applications of moment algorithms for image restoration and demonstrating the benefits of geometric and orthogonal moments are becoming the recent requirements for research.

Keywords: image descriptors, moment algorithm, image blurring, legendre moment, image restoration.

GJCST-F Classification: I.3.3 I.4.4

EXERTINGMOMENTALGORITHMSFORRESTORATIONOFBLURREDIMAGES

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Exerting Moment Algorithms for Restoration of Blurred Images

K. Bhima [α] & Dr. AJagan [σ]

Abstract- In this paper presents the restoration of blurred images which gets degraded due to diverse atmospheric and environmental conditions, so it is essential to restore the original image. The research outcomes exhibit the major identified bottleneck for restoration is to deal with the blurred image as an input to imaging agent employing various methodologies ranging from principle component analysis to momentary algorithms and also a set of attempts are been executed in image restoration using various algorithms. However the precise results are not been proposed and demonstrated in the comparable researches. Also detail understanding for applications of moment algorithms for image restoration and demonstrating the benefits of geometric and orthogonal moments are becoming the recent requirements for research. Hence in this work we undertake the existing moment algorithms to demonstrate the outcome of moments for image restoration and evaluated the Hu, Zernike and Legendre moments and multi-order Legendre order is demonstrated in order to find the best setting of orders for image restoration. The final outcome of this work is a stable version of MATLAB based application to visually demonstrate the performance difference of Hu, Zernike and Legendre moments. The comparative performance of the application is also been demonstrated with the help of multiple image datasets such as fingerprint, bird and human face.

Keywords: image descriptors, moment algorithm, image blurring, legendre moment, image restoration.

I. Introduction

Image processing is a very active research area that has impact in several fields from remote sensing, Biometric authentication system, robotics, traffic Surveillance, to medicine. Automatic target recognition and Tracking, character recognition, 3-D scene analysis and reconstruction are only a few objectives to deal with. Since the real sensing systems are sometimes imperfect and also the environmental conditions are dynamic over time, the acquired images often The image are the for the most part frequent component of information representation and transmission due to the robust nature of information storage and the continuous effort to make digital image processing and presentation better. The studies have shown that the images contain information which is redundant and changing a value may cause errors in the calculation for further steps.

In the space of image processing, the restoration of images is the major expanse of research for many decades. Many researchers have proposed various algorithms and techniques for better restoration of images for various applications. However the collection of image is strongly dependent on the imaging agent. The quality of a image possibly will suffer from a variety of impairments, Still the key bottleneck for better restoration of images are the random distortion and blurring caused to the initial images to be provided as input to the recognition system [1] [2]. The distortion and blurriness of the images are not only dependent on the capture agent, but also depends on the environmental and human errors. The causes of blurriness are studies and classified in four major kinds. Firstly, the focal length of the capture devices, Secondly, during the capture of object in a time irrelevant scale needs to be mapped with the capture speed of the agent to avoid the blurriness [3]. Thirdly, sometimes due to environmental and human causes the stabilization of the capture devices may be disturbed causing the blurriness. Fourthly, the most unavoidable situation, where the object is in higher order of colour range but the relevant background of lower order of colour range causing the blurriness. Thus to remove the effect of blurriness of the image, the most appropriate algorithms to be deployed are the momentary calculation algorithms.

In the field of image processing, computer vision and allied fields, an image moment is a certain particular weighted average (moment) of the image pixels' intensities, or a function of such moments, usually chosen to have some attractive property or interpretation. Image moments are helpful to depict objects after segmentation. Simple properties of the image which are found *via* image moments include area (or total intensity), it's centric, and information about its orientation and Effects of moments in digital image processing for restoration cannot be ignored as supported by related researches. In general moments are the numeric values used to represent the nature of any functions and identify with the significant properties [3] [4]. The following are mostly used moments algorithms are Hu moment, Zernike moment and the well discussed Legendre algorithms.

The moments are superior to principle component analysis for image recognition especially for image recognition [5] [6] [7]. Yet the application of moments algorithms are not been studied for digital image restoration with the comparative results for blur to

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restoration algorithm efficiency mapping. Thus in this work we understand the algorithms of moments calculation proposed by Hu, Zernike and Legendre for image restoration and develop a framework for comparing the visual performance of the restoration process by applying the same algorithms.

This work also demonstrates the effect of multi order Legendre for blurred image restoration. The rest of the work is organized as in Section II we understand the basic constructions of the moment algorithms and possibilities to apply for image restoration, in Section III we consider the Legendre moment in detail, in Section IV we define the components for Blurred image restoration process, in Section V, we demonstrate the proposed framework for Blurred Image recovery using multi-order Legendre moment algorithm, in Section VI we discuss the application constructed for the visual comparison for the blurred image restoration, in Section VII we discuss the results tested on multiple image datasets and in Section VIII we discuss the conclusions and future scope of this work.

II. Image Moments

In Image processing and computer vision processing explore the calculation of image moments or finding the image descriptors is widely accepted. The moment is a calculated on certain weighted average of any pixel taking into account the neighbourhood pixel values. Often the moment is also used to calculate to understand and extract the most significant property of a continuous function [8]. The image moments are widely accepted for image processing and used by all polynomial approaches. In this work we consider the restoration techniques using moments, thus the understanding of moments will be helpful in section IV.

In case of image and vision processing calculating the image moment which is resulting in the image descriptor is performed after the image segmentation. The image properties like area, centroid, pixel values and orientation of any object in the image can be represented using the image moment.

Image moments are classified into three categories such as Raw Moments, Central Moments and Scale invariant Moments [3]. In this work, we understand the moments in details:

a) *Raw Moment*

For a simple two dimensional function, denoted by $f(a,b)$, the raw moment of order (x,y) can be defined as

$$M_{xy} = \int_{-\alpha}^{+\alpha}\int_{-\alpha}^{+\alpha} a^x . b^y . f(a,b).da.dy \qquad \ldots\text{Eq 1}$$

For all positive integers of x and y

The function $f(a,b)$ denoting any greyscale image with pixel intensity of I(a, b) will be denoting the moment as

$$M_{xy} = \sum_a \sum_b a^x . b^y . I(a,b) \qquad \ldots\text{Eq 2}$$

In order to simply the calculations by considering the probabilistic measure for image analysis, the Eq. 2 needs to be normalized by the

$$\sum_a \sum_b I(a,b).$$

b) *Central Moment*

For a simple two dimensional function, denoted by $f(a,b)$, the central moment of order (x,y) can be defined as

$$\mu_{xy} = \int_{-\alpha}^{+\alpha}\int_{-\alpha}^{+\alpha} (a-\bar{a})^x . (b-\bar{b})^y . f(a,b).da.dy \qquad \ldots\text{Eq 3}$$

Where the $\bar{a}$ and $\bar{b}$ are the generic components of the centroid of the image and can be defined as

$$\bar{a} = \frac{M_{10}}{M_{00}} \text{ and } \bar{b} = \frac{M_{01}}{M_{00}} \qquad \ldots\text{Eq 4}$$

In case of a digital image, the Eq. 4 can be represented as the following:

$$\mu_{xy} = \sum_a \sum_b (a-\bar{a})^x . (b-\bar{b})^y . f(a,b) \qquad \ldots\text{Eq5}$$

The central moments for order k can be represented as

$$\mu_{xy} = \sum_{k_1}^{x} \sum_{k_2}^{y} \binom{x}{k_1} . \binom{y}{k_2} . (-\bar{x})^{(x-k_1)} . (-\bar{y})^{(y-k_2)} . M_{k_1 k_2} \qquad \ldots\text{Eq 6}$$

The central moments are considered as translation invariant.

c) *Scale invariant Moment*

The moment of order (x + y) where x + y ≥ 2 can be obtained by dividing the central moment with 0^{th} moment as following:

$$M_{xy} = \frac{\mu_{xy}}{\mu_0^{\left(1+\frac{x+y}{2}\right)}} \qquad \ldots\text{Eq 7}$$

The scale invariant is neutral for scale change.

III. Applicability of Legendre Moment

The most adopted method for image pattern or image restoration is the use of moments. The recent advancements demonstrate the use of moment calculation methodologies as geometric and orthogonal moments. Further studies have demonstrated that the orthogonal moments are better than the geometric moments. Among the orthogonal moments the most widely accepted method is to deploy the Legendre moment. But the application of Legendre moment is also restricted for the blurred or distorted images. Here we understand Legendre Moments in detail [3] [13]:
Legendre Moment for of order (a + b) is defined as:

$$\lambda_{ab} = \frac{(2a+1)(2b+1)}{4} \int_{-1}^{+1}\int_{-1}^{+1} P_a(i).P_b(i,j).didj \qquad \ldots\text{Eq 8}$$

Where a, b is ranging from 1 to∞.
Hence the kth order Legendre polynomial is written as:

$$P_k(i) = \frac{(2k)!}{2^k(k!)^2} i^k - \frac{(2k-k)!}{2^k!(k-1)!(k-2)!} i^{k-2} + \ldots \text{ K}^{th} \text{ Term} \qquad \ldots\text{Eq9}$$

Where, D(k) = k/2 or (k-1)/2, is an positive integer.

IV. Characteristics of Blurred Image

In the Blurred or noisy image, the objects vary in terms of contrast and size. The objects in the image can represent large to small item or the items with detailed visibility. The primary effect of the blurriness on the imageis to reduce the contrast and visibility of the images. The reduced visibility images causes less detailed information in the images [10] [11].

The objects in the images are generally differentiated by the pixel difference between the object and the background at the object edges. The blurriness of the image actually reduces the pixel difference at the object edges [12].

The blurriness of the image can be measured in terms of units of lengths. The length of the images denotes the blurriness of the image [Table – I].

Table I : Blur Value Range

Capture Agent Type	Range of Blur Value (In MM)
Gamma Ray Camera	10 to 2
Ultrasonic Camera	5 to 2.1
Magnetic Resonance Camera	3.4 to 1
Computed Thermography Camera	2 to 1.3
Motion Capture Camera	2.8 to 0.3
Radio Active Camera	0.5 to 0.1

V. Framework for Blurred Image Restoration Process

The two dimensional Legendre Moment for the blurred image of g (a, b) can be defined as [3] [13]:

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} P_x(a).P_y(b).g(a,b).dadb \qquad \ldots\text{Eq10}$$

With the understanding of blurriness effect on the image, the image pixel will be multiplied by random value generated by the noise function.

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} P_x(a).P_y(b).(f*h).dadb \qquad \ldots\text{Eq 11}$$

Legendre moment of the blurred image can be represented as

$$L_{x,y}(g) = \int_{-1}^{+1}\int_{-1}^{+1} h(i,j).(\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} P_x(a+i).P_y(b+j)f(a,b)dadb).didj \qquad \ldots\text{Eq 12}$$

Image restoration procedure using moments:-

- Capturing image using capture device.
- Captured image is stored and referred for pre processing
- Blur function is applied on Image and also calculates image moment using Legendre polynomials.
- Comparison of original blurred and restored image.

Thus the process of restoring the blurred image using Legendre Moment is presented in this work [Figure – 1].

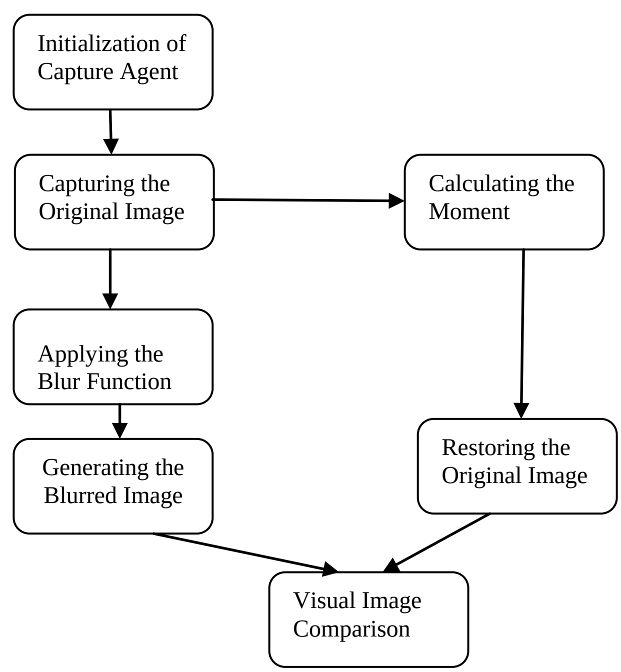

Figure 1 : Framework for Blurred Image Restoration

VI. Real Time BLurred Image Restoration

In order to prove the findings and theoretical framework proposed in this work, we provide the MATLAB implementation of this framework to test the

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visual advantages of Legendre Moments over other available moments. MATLAB is a highly popular multipurpose numeric programming language for the wide variety of build in library functions ranging from image processing to higher order numeric calculation. The built in library is capable of generating matrix based calculation and graph plotting in multi-dimensional space. The MATLAB is considered as the fourth generation programming language.

In the implementation we also propose the multi order Legendre Moments to restore the blurred and noisy image.

VII. Results and Discussions

In this section, we have considered three different image dataset of fingerprint, bird and human face for restoration using various methods such as Hu, Zernike and Legendre moments.

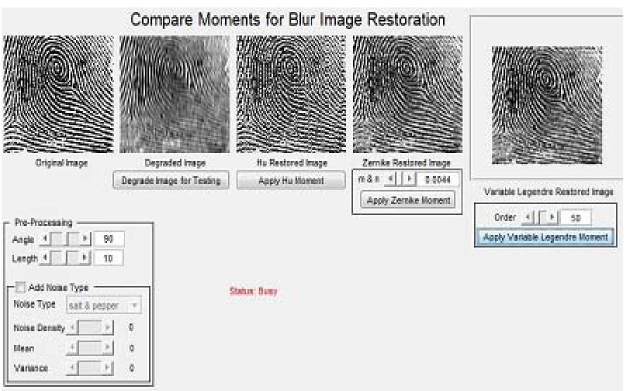

Figure 2. 1 : Restoration of fingerprint Image using moments

The input fingerprint image is blurred with length of 10mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.1].

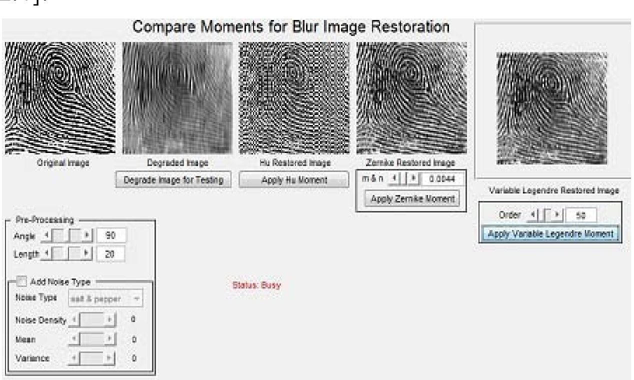

Figure 2. 2 : Restoration of fingerprint Image using moments

The input fingerprint image is blurred with length of 20mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.2].

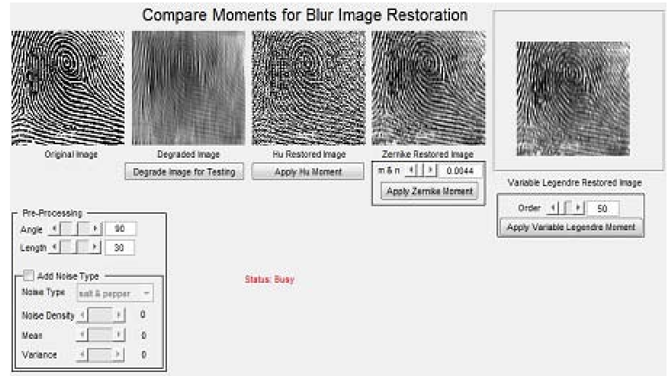

Figure 2. 3 : Restoration of fingerprint Image using moments

The input fingerprint image is blurred with length of 30mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.3].

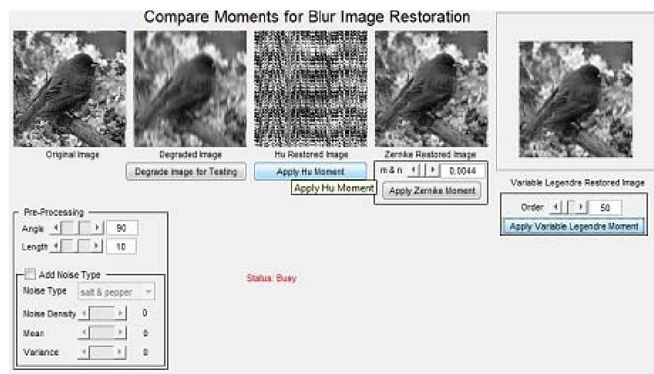

Figure 2. 4 : Restoration of Bird Image using moments

The input bird image is blurred with length of 10mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure _ 2.4].

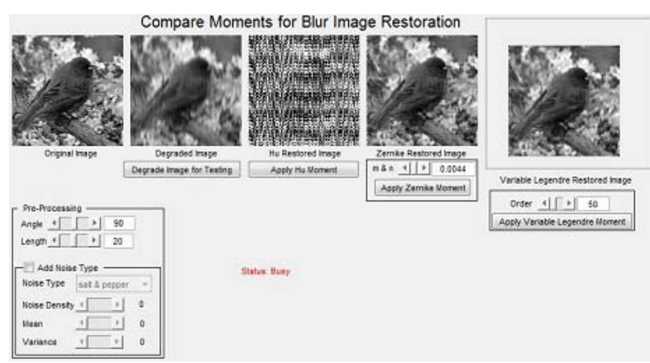

Figure 2. 5 : Restoration of Bird Image using moments

The input bird image is blurred with length of 20mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.5].

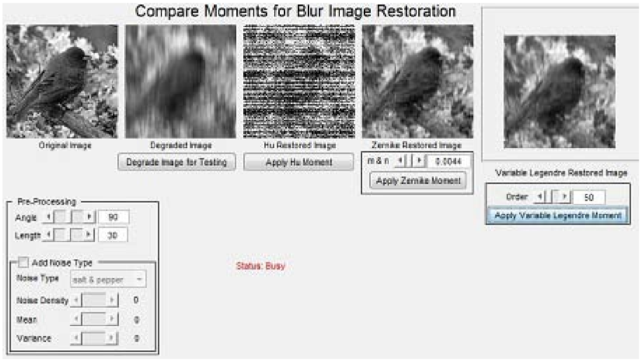

Figure 2.6 : Restoration of Bird Image using moments

The input bird image is blurred with length of 30mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.6]

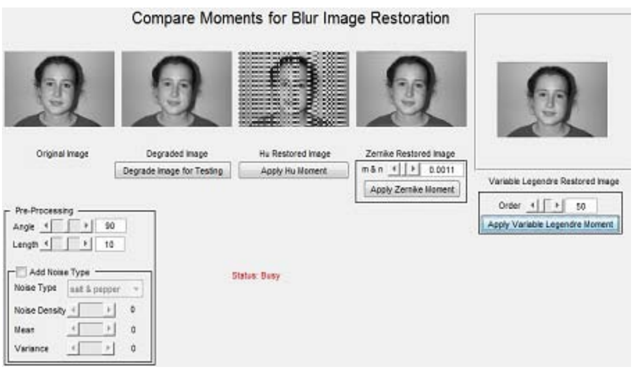

Figure 2.7 : Restoration of Face Image using moments

The input face image is blurred with length of 10mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.7]

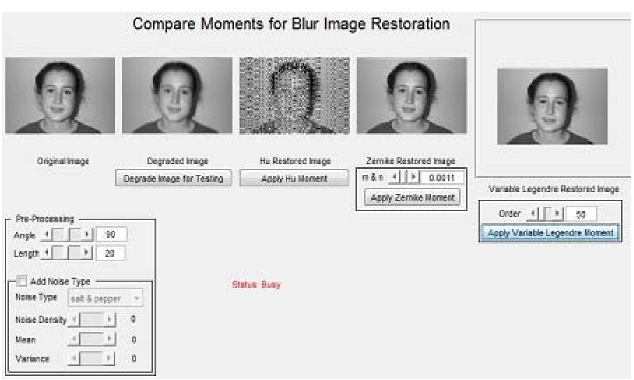

Figure 2. 8 : Restoration of Face Image using moments

The input face image is blurred with length of 20mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.8]

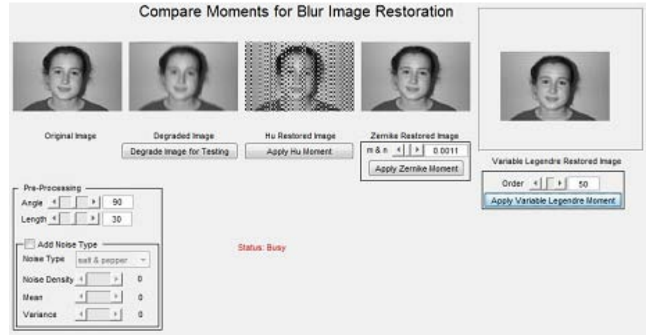

Figure 2. 9 : Restoration of Face Image using moments

The input face image is blurred with length of 30mm and been tested for restoration with Hu, Zernike and Legendre moments of 50 order [Figure – 2.9]

Henceforth we compare the initial image and restored image generated by the Hu, Zernike and Legendre moments using the following formulation:

The difference between the original image and the restored image using movements' algorithms considered as K_1 and the difference between the original image and blurred image is considered as K_2.

Hence the comparative difference between the K_1 and K_2 is considered K, demonstrating the amount of successful restoration for any given image using any given moment algorithm.

$$\left|\det(I_{ori}) - \det(I_{res(Moment)})\right| = K_1 \quad \text{...Eq 13}$$

$$\left|\det(I_{ori}) - \det(I_{blur})\right| = K_2 \quad \text{...Eq 14}$$

$$|K_1 - K_2| = K, K_1 \rightarrow 0, K \rightarrow K_2 \quad \text{...Eq 15}$$

Table II : Comparative Study of Hu, Zernike and Legendre moment based on K value in Eq. 15.

For dataset of fingerprint, bird and human face

Input Image	Blur Length	Hu Moment (In %)	Zernike Moment (In %)	Legendre Moment (In %)
Fingerprint	10 mm	78	65	53
	20 mm	80	68	58
	30 mm	83	71	68
Bird	10 mm	23	63	71
	20 mm	24	68	75
	30 mm	24	71	79
Human Face	10 mm	37	53	81
	20 mm	41	57	83
	30 mm	53	61	87

The testing results clearly demonstrate the comparative study on different data sets such as fingerprint, bird and human face for restoration using Hu, Zernike and Legendre moment. For fingerprint Hue method exhibit better results, Zernike and Legendre shows better results for bird. In the case of human face Legendre moments demonstrates better results.

VIII. Conclusion

In this paper focus on the analysis of three categories of moments such as Raw Moments, Central Moments and Scale invariant Moments and the basic mathematics functions behind those moments. In order to achieve better understanding of image restoration process, we have also understood the nature of blurred images. The understanding of the difference of lengths for normal and blurred image based on the length for various capture device types. Henceforth, this work proposes a theoretical framework using Hu, Zernike and Legendre moment to restore blurred images. The theoretical model is also validated using the image dataset and the results are also been tested. The result of image dataset is satisfactory for restoring the blurred images. The application is been tested on three types of image such as Fingerprint, bird and human face. For majority of the image restoration Legendre moments demonstrate good results.

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Improved Image Denoising Filter using Low Rank & Total Variation

By Garima Goyal
Visvervaraya Technological University, India

Abstract- Better diagnosis of disease is possible only with the better microscopic images. To do so images of the affected area are captured and then noise is removed to obtain accurate diagnosis. Many algorithms have been proposed till date. But they are capable of removing noise only in spatial domains so this paper tries to overcome that by combining low rank filter and regularization. If we only reduce noise in spatial or spectral domain, artefacts or distortions will be introduced in other domains. At the same time, this kind of methods will destroy the correlation in spatial or spectral domain. Spatial and spectral information should be considered jointly to remove the noise efficiently. Low rank algorithms are good as they encloses semantic information as well as poses strong identification capability.

Keywords: filter, low rank, regularisation, noise, tem image.

GJCST-F Classification: H.2.8 I.3.3

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Strictly as per the compliance and regulations of:

Improved Image Denoising Filter using Low Rank & Total Variation

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Abstract- Better diagnosis of disease is possible only with the better microscopic images. To do so images of the affected area are captured and then noise is removed to obtain accurate diagnosis. Many algorithms have been proposed till date. But they are capable of removing noise only in spatial domains so this paper tries to overcome that by combining low rank filter and regularization. If we only reduce noise in spatial or spectral domain, artefacts or distortions will be introduced in other domains. At the same time, this kind of methods will destroy the correlation in spatial or spectral domain. Spatial and spectral information should be considered jointly to remove the noise efficiently. Low rank algorithms are good as they encloses semantic information as well as poses strong identification capability.

Keywords: filter, low rank, regularisation, noise, TEM image.

I. Introduction

The transmission electron microscope (TEM) is used to examine the structure, composition, and properties of specimens in submicron detail. Aside from using it to study general biological and medical materials, transmission electron microscopy has a significant impact on fields such as: materials science, geology, environmental science, among others.Various TEM image denoising algorithms have been proposed in the recent years [1][2][3][4]. At a maximum potential magnification of 1 nanometer, TEMs are the most powerful microscopes. TEMs produce high-resolution, two-dimensional images, allowing for a wide range of educational, science and industry applications.

All the algorithms remove the noise in only in spatial domain which in turn deteriorate correlation in spectral domain. Highly correlated images set have the nature of low rank; they can be recovered efficiently from measurement with noise or outliers by using the restriction of low rank [5][6][7]. While sparse coding and dictionary learning a error was introduced which can be reduced by imposing a low rank algorithm. To make the problem solvable total variation, i.e regularization will be used.

II. Literature Survey

Low rank approximation is good for recovering low dimensional structures in data. It is been in use in variety of applications in image and video processing. A new denoising algorithm based on iterative low-rank regularized collaborative filtering of image patches under a nonlocal framework. This collaborative filtering is formulated as recovery of low rank matrices from noisy data. Based on recent results from random matrix theory, an optimal singular value shrinkage operator is applied to efficiently solve this problem [8]. A sparse banded low pass filter is discussed which showed significant improvement in PSNR [9]. A combined denoising strategy, and adaptive dimensionality reduction approach of similar patch groups by parallel analysis was used which indicated appropriate results [10]. A image Deblurring using split bergman iterative algorithm was proposed characterizing both image local smoothness and non local self similarity [11].

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III. Algorithm

It solves following optimization problem

min_X || Y-X||_1 + lambda ||Dh*X||_1 + lamdba ||Dv*X||_1 + mu ||X||_* (3.1)

Here in this equation, X is the Input TEM image, Y indicates the Noisy image, Dh & Dv are the horizontal and vertical finite difference operators, ||X||_* means the Nuclear norm of matrix X. We utilize split-Bregman technique to solve above problem. Before running the algorithm we set the mu(1), mu(2), mu(3) which corresponds to total variation term, low rank term and data fidelity term respectively.

1. img=imread('ctem.jpg');
2. img=im2double(img);
3. [rows,cols,d]=size(img);
4. sizex=[rows,cols];
5. noisy = imnoise(img,'salt & pepper',0.02);
6. psnrBefore=findPSNR(img,noisy,1);
7. y=reshape(noisy,rows*cols,d);
8. mu=[.2 .2 .5]; iter=10;
9. x=basicDenoising(y,sizex,mu,iter);
10. psnrRec=findPSNR(img,x,1);
11. bands=[1 floor(d/2) d]; %these are the bands to be displayed
12. img=myhisteq(img);rec=myhisteq(x); noisy=myhisteq(noisy);
13. subplot(131); imshow(img(:,:,bands)); title('Original Image');

```
14. subplot(132); imshow(noisy(:,:,bands)); title('Noisy
    Image');
15. subplot(133); imshow(rec(:,:,bands));
    title('Reconstructed Image');
function x = basicDenoising(y,sizex,mu,maxiter)
1. mu1=mu(1) ; mu2=mu(2); mu3=mu(3) ;
2. [~,d]=size(y);rows=sizex(1);cols=sizex(2);
3. B1=zeros(rows*cols,d); B2=B1; B3=B1; B4=B1;
4. [Dh,Dv]=TVR(rows,cols);
5. x=zeros(rows*cols,d);
6. for i=1:maxiter
P=Sfth(Dh*x+B1,1/mu1);
            Q=Sfth(Dv*x+B2,1/mu1);
            R=Nnth(x+B3,1/mu2);
            S=Sfth(y-x+B4,1/mu3);

            bigY=Dh'*(mu1*(P-
B1))+Dv'*(mu1*(Q-B2))+mu2*(R-B3)+mu3*(y-S+B4);
            for j=1:d
            [x(:,j),~]=lsqr(@find,bigY(:,j),1e-
6,5,[],[],x(:,j));
            end
            B1=B1+Dh*x-P;
            B2=B2+Dv*x-Q;
            B3=B3+x-R;
            B4=B4+y-S-x;
            if rem(i,2)==0
                fprintf(' %d iteration done of %d
\n',i, maxiter);
            end

end
7. x=reshape(x,rows,cols,d);
end
 function y = find(x,str)
1. tt= mu1*(Dh'*(Dh*x))+ mu1*(Dv'*(Dv*x))+ mu2*x
   + mu3*x;
2. switch str
case 'transp'
y = tt;
      case 'notransp'
            y = tt;
    end
end
function X= Sfth(B,lambda)
1. X=sign(B).*max(0,abs(B)-(lambda/2));
end
function X=Nnth(X,lambda)
1. if isnan(lambda)
            lambda=0;
end
2. [u,s,v]= svd(X,0);
3. s1=Sfth(diag(s),lambda);
4. X=u*diag(s1)*v';
end
```

```
function [Dh, Dv]=TVR(m,n)
1. Dh = spdiags([-ones(n,1) ones(n,1)],[0 1],n,n);
2. Dh(n,:) = 0;
3. Dh = kron(Dh,speye(m));
4. Dv = spdiags([-ones(m,1) ones(m,1)],[0 1],m,m);
5. Dv(m,:) = 0;
6. Dv = kron(speye(n),Dv);
end
```

IV. Results

The algorithm is implemented in MATLAB. A nanoscopic TEM is taken and salt & pepper noise is added. Then the filter is applied to denoise the image. Peak Signal to noise ratio is evaluated before and after applying the filter. One sample result is indicated below.
PSNR before denoising : 14.92
PSNR after denoising : 27.87

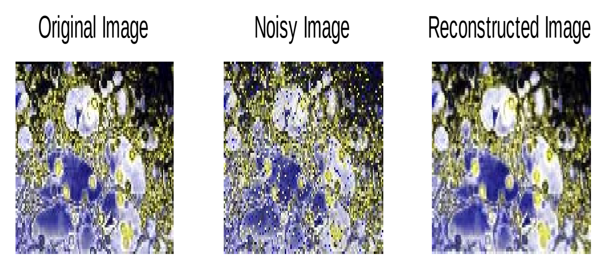

Figure 4.1 : Results before and after applying the Filter

V. Conclusion

By introducing ideal regularization term and performing low rank matrix recovery we are able to denoise image successfully without losing structural information. The peak signal to noise ratio obtained is significantly much higher and quite significant.

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Face Recognition using Fused Diagonal and Matrix Features

By Jagadeesh H S, Suresh Babu K & K B Raja
APS College of Engineering, India

Abstract- Face recognition with less information availability in terms of the number of image samples is a challenging task. A simple and efficient method for face recognition is proposed in this paper, to address small sample size problem and rotation variation of input images. The robert`s operator is used as edge detection method to elicit borders to crop the facial part and then all cropped images are resized to a uniform 50*50 size to complete the preprocessing step. Preprocessed test images are rotated in different angles to check the robustness of proposed algorithm. All preprocessed images are partitioned into one hundred 5*5 equal size parts. The matrix 2-norm, infinite norm, trace and rank are elicited for each of 5*5 part and respectively averaged to yield on hundred matrix features. Another one hundred diagonal features are extracted by applying a 3*3 mask on each image. Final one hundred features are obtained by fusing averaged matrix and diogonal features. Euclidian distance measure is used for comparision of database and query image features. The results are comparitively better on three publically availabe datasets compared to existing methods.

Keywords: cropping, edge detection, rotation variation, small sample size problem.

GJCST-F Classification: *I.4.8 I.7.5*

FACERECOGNITIONUSINGFUSEDDIAGONALANDMATRIXFEATURES

Strictly as per the compliance and regulations of:

Face Recognition using Fused Diagonal and Matrix Features

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Keywords: cropping, edge detection, rotation variation, small sample size problem.

I. Introduction

Prevailing of a single technology over a long period of time is difficult. Many approaches provided solution to issues related to cognitive detection and recognition of human. The assumptions are deciding factors in most of approaches, because of flaws in predicting the sources of errors for real-time situations. Recognizing humans using faces has many influencing parameters, which are categorized under constrained and unconstrained environments. There is no exact definition of unconstrained environment, but the randomness in overall process is the key factor. Real time situations are elusive i.e. to capture face image under movement of a person, in race, at distance [1], low resolutions, and different internal or external human activities. Surveillance and vigilance applications are the best example for the same. Various physical constraints such as illumination [2], occlusion, pose, expression and disguise have vital influence on performance of recognition system. Representing digital face images through imaging against to these constraints in Visible Spectrum (VS) limits the usage of samples. Remedy is to capture images in Infrared Spectrum (IS) [3] which is robust to VS influencing parameters. Additionally the imaging is based on the pattern of blood vessels of face, which does not vary with age. The recognition accuracy is greatly influenced by physiological and eyeglass problem in IS, which limits its applications.

Another factor of interest is Dimension Reduction (DR), where the input image data is transformed into less quantity by retaining vital information. DR is to reduce memory requirement and computations. Linear and nonlinear methods [4] are used for the same. Independent Component Analysis (ICA), Linear Discriminant Analysis (LDA) and Principal Component Analysis (PCA) are the three approaches in linear DR category. Original image structure is preserved using Random Projections (RP) by nonlinear methods. RP has the advantage of data independence and low computational complexity [5]. Various feature descriptors [6] are proposed to represent data appropriately towards variation in rotation, such as Short Term Fourier Transform (STFT), Scale Invariant Feature Transform (SIFT) [7]. The advantage of SIFT made it to use widely, but suffers partially from illumination changes. No algorithm has declared that it is ideal for all the challenges involved by using complete repertoire for face recognition problem. Different methods proposed by various researchers considered either one or fewer number of challenges. The issues such as rotation of images for testing purpose and fewer samples of images are considered in the proposed method.

II. Literature Review

Xiaoyang Tan, et al., [8] made a detailed survey on one sample size problem. The challenges, significance, and different methods used to recognize human faces with single image are discussed. Obtaining accuracy with less number of images and difficulty in acquiring many samples are key challenges. Even with DR techniques, storing and processing time improvements are significant factors. Conventional methods such as PCA, LDA and extensions either individually or in hybrid manner are used as feature extraction techniques. The accuracy of various approaches on different face databases is compared. Kin-Man Lam, and Hong Yan [9] proposed an approach for identifying faces using analytic to holistic concept. Forty frontal view faces are considered for test database. Using fifteen feature points of each face with

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head model, rotation of the face is estimated. Face feature points of database and feature points of front view image are compared using similarity transform. Comparison is repeated using correlation by setting up windows for mouth, nose, and eyes. Results obtained are similar on Olivetti Research Laboratory (ORL) face database as with different face viewing directions.

Yu Zhao, et al., [10] investigated a framework for face recognition, which is useful in conference socialization scenarios. Using an arbitrary view of a subject as query image with only frontal images used for training images the framework is proposed. It consists of a feature point detection scheme, feature area smoothing and feature mapping. The registration process of conference participants is completed using a frontal photo. A mobile phone camera is used to acquire probe image with an arbitrary angle at the conference for identifying a person. Experimental results are robust to pose variations on FERET dataset and two self-collected conference socializing datasets. Kuo-Chin Fan and Tsung-Yung Hung [11] proposed a local pattern descriptor named Local Vector Pattern (LVP) for face recognition. The micro patterns are generated using high-order derivative space with pixel level computations. Performance of LPV is better compared with Local Binary Pattern (LBP), local tetra pattern, and local derivative pattern descriptors on FERET, CAS-PEAL, CMU-PIE, Extended Yale B, and LFW face databases.

Zhen Lei et al., [12] introduced a data-driven Discriminant Face Descriptor (DFD) using image filters, optimal neighborhood sampling and dominant patterns. It is able to extract discriminant features for the images of different persons compared to different images of same person. DFD is applied to heterogeneous face recognition problem also. Experiments on FERET, CAS-PEAL-R1, LFW, and HFB face databases validate the ability of DFD. Zhenhua Guo et. al., [13] proposed a hybrid LBP scheme for texture classification using locally variant LBP features and globally rotation invariant matching. Principal orientations are estimated and aligned for texture image based on LBP distribution. Dissimilarity measure between images is performed based on LBP histograms. LBP variance (LBPV) texture descriptor is also developed for exploiting the local contrast information. In addition to this, the time required for matching is reduced by a feature size reduction method. Higher classification accuracy is obtained on Outex and Columbia-Utrecht (CUReT) texture database compared with traditional rotation invariant LBP methods. Jiansheng Chen, et al., [14] introduced a face image quality assessing framework. Rank based quality score is used in registration for face quality control and recognition is performed by selecting the high quality face images. The results on Chinese ID card photo database, FRGC, FERET, LFW and AFLW face databases has superior performance compared to conventional methods.

III. Block Diagram of the Proposed Model

The details of input data, preprocessing, features extraction and matching are discussed in this section. Figure 1 shows the block diagram of proposed Face Recognition using Diagonal and Matrix Features (FR DMF) model.

a) Databases

i. Yale database [15] consists of 15 subjects, each subject with 11 different images with a total of 165 images in Graphics Interchange Format (GIF). The either variation in facial expressions such as neutral, happy, sleepy, surprised, sad, and wink or different configurations such as left-light, center-light, right-light, wearing glasses, without wearing glasses are considered. Dimension of each image captured has 243*320 size and 24 bit pixel depth. All images have 96 dpi horizontal and vertical resolutions. The GIF is converted to JPEG in the proposed work.

ii. Kinect face database [16] has 468 images with nine types of expressions under different occlusion and lighting variations. Nine images of 52 subjects are captured in two sessions, with in a fortnight consisting of 38 male and 14 female persons. Expressions such as neutral, smile, opening mouth, left profile, right profile and occlusion in eyes, mouth, paper, wearing glasses are considered. The images are acquired at one meter distance in EURECOM Institute laboratory. Each pixel is represented by 24 bit with 256*256 image size in Bitmap format.

iii. Indian face database [17] contains images of 39 male and 22 female subjects for eleven different pose variations per person. Totally it has 671 images are in frontal position with bright homogeneous background. Different poses include; looking front, looking left, looking right, looking up, looking up towards left, looking up towards right, and looking down. Neutral, smile, laughter, sad / disgust expressions are incorporated during image capturing. Each image has the spatial resolution of 640x480 pixels, with 24 bits per pixel in JPEG format and 96 dots per inch.

Figure 2 shows one image sample each of Yale, Kinect and Indian face database respectively.

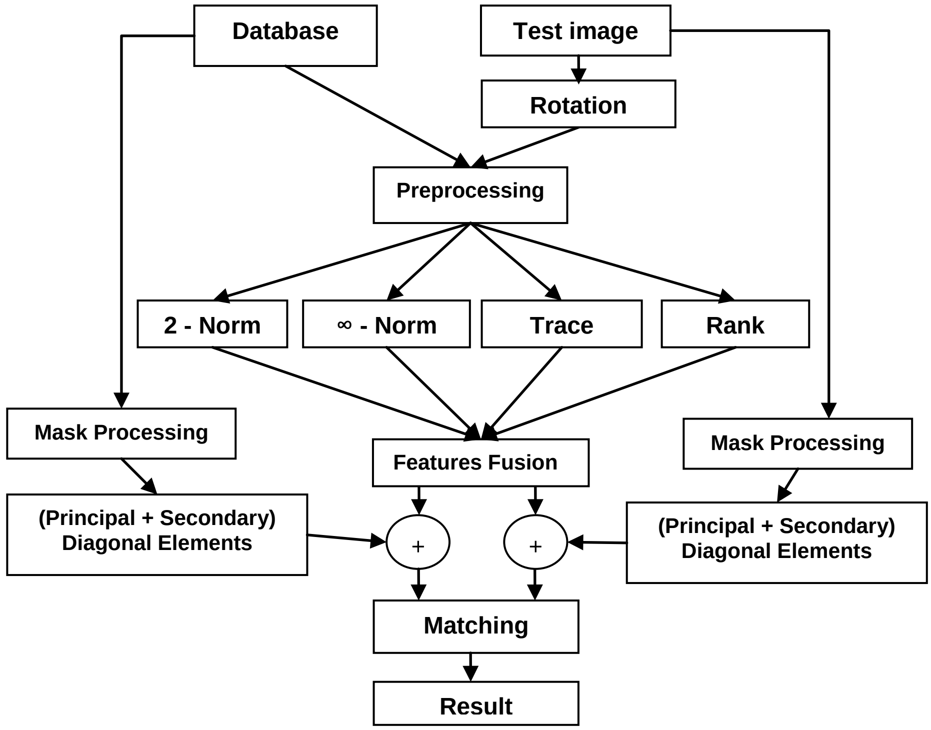
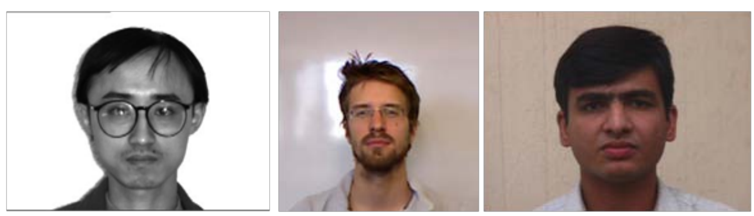


Fig. 1: Block diagram of the Proposed FR DMF model



(a) (b) (c)

Fig. 2: Sample images of three databases (a) Yale, (b) Kinect, and (c) Indian database

b) Pre-processing

Figure 3 shows the result of preprocessing for input image 3 (a) The significance of preprocessing is to refine the input image for any noise associated and to remove any unwanted trivial information content, which do not contribute vital part of face image e.g. background. The preprocessing involves; (i) RGB to gray conversion (optional), (ii) Boundary detection using Roberts edge operator, (iii) Scanning; (iv) Cropping, and (v) resizing. The conversion of any type of image to gray form reduces the dimension of each image to one dimension with appreciable quality. Further it reduces the burden in number of computations. Using Roberts's operator or mask the edges are emphasized and the two different forms of Roberts's operators are given in Table 1. Edges are identified based on the maximum value of gradient between input image and the mask at any point. It is non symmetric and fails to detect edges at 45^0 multiples [18]. The output image after applying Roberts's edge operator is shown in Figure 3 (b).

Table1: Roberts Operator

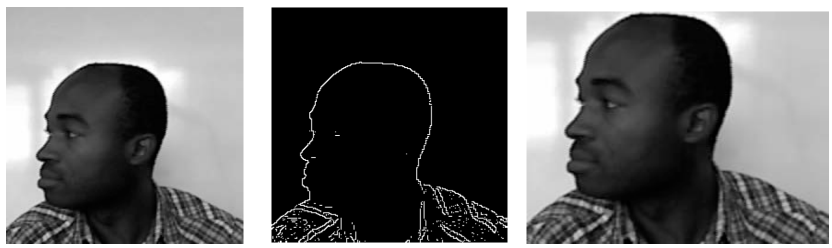
-1	0
0	1

0	-1
1	0

In the next step the whole image is divided into two parts in column wise. First 25 columns are searched in each row for the edges, as soon as it finds an edge, it stops searching and the corresponding coordinates are noted both in X and Y direction. Similar steps are carried out for the remaining columns but in opposite direction. As the Roberts operator produces high at edges which is useful to refine the facial part in the input image through scanning. Based on the scanned information the all images are cropped to different sizes. Finally all images are resized to 50*50 uniformly to complete the preprocessing step as shown in Figure 3(c). Only preprocessed test images are rotated with any one of different angles such as +/-1^0, +/-2^0, +/-3^0, +/-4^0 and +/-5^0 to observe the robustness of proposed method.

c) Feature extraction

The aim of extracting features is to compress the preprocessed image such that it should retain original information. Features derived should have the distinct quality and uniquely represent the original image. In the proposed work, four simple matrix features are elicited and fused. The preprocessed image of Size 50*50 is divided into ten equal non overlapping parts with 5*5 sizes each and is shown in Figure 4. On each part of the segmented image matrix 2-norm, infinite norm, trace and rank of the matrix are separately calculated. For each 5*5 segment of image four different matrix features are obtained, totally one hundred matrix 2-norm, infinite norm, trace and rank of the matrix features generated respectively. Finally these features are normalized and algebraically averaged to get final unique coefficients. Figure 4 is the segmented input image.



(a) (b) (c)

Fig. 3: Pre-processing result on a Kinect database image (a) Gray scale image, (b) Output of Edge detection, (c) Cropped image

Fig. 4: Segmented image with each fragment size of 5*5

In a vector space containing real and complex numbers denoted by K^{m*n}, where K is the field of numbers with m rows and n columns. Vector norm of a matrix A in K space is also named as induced norm and denoted as $||A||$. The general definition of matrix norm is the maximum value of absolute sum of elements in specific dimension [19]. Consider an input matrix A

$$= \begin{pmatrix} 1 & 2 & -3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix}$$

The 1- norm is the maximum value in each column sum, obtained for absolute value of elements column wise and 1-norm for matrix is given by $||A||_1$ = Maximum [(1+4+7),(2+5+8), (|-3|+6+9)] = Max[12,15,18] = 18. Similarly ∞ -norm is the maximum value in each row sum, obtained for absolute value of elements row wise and ∞ -norm [20] for matrix is given by $||A||_\infty$ = Maximum [(1+2+|-3|), (4+5+6), (7+8+9)] = Max[6,15,24] = 24. $||A||_2$ is the 2- norm which is the largest singular value of matrix A, where singular values are the square root of Eigen values of A^TA. The value of $||A||_2$ obtained for matrix A is 16.84 and it is also named as Euclidean and spectral norm.

Trace of a matrix is defined as the sum of diagonal elements in the matrix and which is similar to the sum of singular values of a matrix [21]. Finally, rank of a matrix is the number linearly independent columns or rows of a matrix. In our work, the rank [22] of segmented part of the image is considered. For the matrix A, trace is given by (1+5+9) = 15 and rank is 3. Table 2 infers the result of rotation with +/- 1^0 in these matrix parameters. Additionally it contains matrix 2-norm, Infinite norm, Trace, Rank of the matrix and averaged value of all these features.

On the other side, each original image pixel is computed by taking the difference between the maximum and minimum of pixel intensities within 3*3 overlapping mask. Then the principal and secondary diagonal elements are averaged to get another one hundred diagonal features. Table 3 depicts the process of obtaining diagonal features. The final one hundred features are obtained by fusing these diagonal features with the one hundred averaged matrix features.

d) Matching

One hundred fused features of each image are stored as database; these features are to be compared with the corresponding features of probe images. Euclidean Distance (ED) measure is used for the comparison of database and probe image features. The ED between any two vectors *P* and *Q* is given in Equation (1), where *'i'* vary from one to total number of elements in each vector.

Table 2 : Matrix features comparison for a resized 5*5 image

Rotation angle	Original Image					2-norm	∞-norm	Trace	Rank	Average
-1^0	168	101	36	155	153	585.7	613	468	5	417.9
	193	73	26	133	186					
	167	64	35	151	172					
	144	37	20	115	156					
	75	46	26	60	77					
0^0	213	112	56	181	203	660.1	765	517	5	486.7
	213	61	22	124	201					
	190	60	35	147	193					
	164	32	19	109	176					
	108	51	30	65	99					
1^0	160	92	39	165	157	586.1	613	444	5	412
	195	71	25	137	181					
	170	65	35	152	172					
	147	40	19	108	154					
	84	50	25	55	70					

Table 3 : Result of masking with diagonal features

Original Image					Mask Processed Image					Principal Diagonal Elements	Secondary Diagonal Elements	Average
188	196	197	195	190	91	139	124	129	22	91	22	56.5
212	121	73	180	202	151	188	173	178	72	188	178	183.0
209	61	24	130	199	168	188	156	178	72	156	156	156.0
175	44	26	133	188	165	185	109	175	129	175	185	180.0
119	45	26	70	113	131	149	107	162	118	118	131	124.5

$$D(Pi, Qi) = \sqrt{((p1 - q1)^2 \ + \ (p2 - q2)^2 \ \ +..} \quad (1)$$

A reference parameter named threshold is considered to compare and produce the results. Threshold is varied from 0 to 1 insteps of 0.1 and compared with the computed values of ED. Matching has two stages; (i) Probe images are within database; If the value of ED is lesser than threshold value and the image corresponding to right person is matched, Then matched person count is incremented by one, which accounts to the computation of Recognition Rate (RR) of the system. If ED value is less than the threshold, but not matching to right person, and then it leads to the calculation of mismatch count. Further, if ED value is greater than the threshold, it is considered as rejected the right person and is in the name of False Rejection Ratio (FRR). (ii) Probe images are out of database; As the name says the test images are taken out of the database and the procedure explained for FRR computation is repeated. If ED value is less than the threshold, match count is incremented which should be understood as unknown person is falsely accepting. The decision is made as unknown person is rejected correctly, when the ED value is higher than the threshold.

IV. Algorithm

Problem definition: The Face Recognition system with Diagonal and Matrix Features (FR DMF) model is used to identify a person. Proposed algorithm of the FR DMF model is described in Table 4 with the following objectives:

(i) To increase Recognition Rate (RR) or Total Success Rate (TSR)
(ii) To limit the value of FRR and FAR.

Table 4 : Algorithm of Proposed FR DMF model

Input: Face Images of Database and for query.
Output: Identifying / discarding of a person.

1. Preprocessing has following five steps
   (i) RGB to gray conversion (optional)
   (ii) Edge detection using Roberts operator
   (iii) Image Scanning
   (iv) Image Cropping
   (v) Image Resizing to 50*50
2. Only preprocessed test images are rotated in any one of +/-1^0, +/-2^0, +/-3^0, +/-4^0 and +/-5^0
3. All images of 50*50 size is partitioned into 100 pieces with each piece has 5*5 size
4. For each piece of 5*5, matrix 2-norm, infinite norm, trace and rank are computed.
5. For each 50*50 image, 100 coefficients are extracted using Matrix 2-norm, Infinite norm, Trace and Rank separately and averaged to yield one set of 100 features.
6. Using a 3*3 mask for each image pixel (without preprocessing), the difference between maximum and minimum is computed and resized to 100*100.
7. Principal and secondary diagonal elements, 100 each for the output of step 6 are added with 100 features of step 5 to get final features
8. Between the feature vectors of database and test images, Euclidean distance is computed.
9. For the image with minimum Euclidean distance, matching is decided.

V. Performance Evaluation

Performance of the proposed algorithm is tested on three publically available datasets such as Yale, Indian and Kinect face database. The objective is to test the algorithm for two parameter variations i.e. number of trained images and through image rotation. To make it clear the number of trained images used are limited to either one or two and only the test images are rotated in different angles viz. +/-1^0, +/-2^0, +/-3^0, +/-4^0 and +/-5^0. Anticlockwise rotation is considered as positive and clockwise is negative. Results are extracted by fixing the number of trained images either one or two for all the image rotation angles.

(i) *Yale database.* The images of 13 persons are used for database creation. Tenth image of 13 persons is used for FRR is computation and FAR is computed by using 5th image of remaining two persons. Performance is tested for single and double trained images case. The rotation invariance property is observed for +/-1^0, -2^0, +/-3^0, and +/-4^0 as in Table 5, where the maximum % RR is 53.8 for single trained image case. Similarly for two trained images it is exhibiting rotation invariance in 0^0, 1^0, 2^0, 3^0 and 4^0 rotation angles, the maximum % RR of 92.3 is obtained for the same. Figure 5 shows the plot of Threshold in X-axis with FAR and FRR in Y-axis for (a) Single and (b) Double trained images with 1^0 and 0^0 rotation respectively. Figure 6 consolidates the maximum % RR rotated in different angles on Yale database for single and double trained images. An average % RR of 52.2 and 90.7 is obtained respectively for single and double trained images for rotation angles mentioned in Figure 6. Table 6 compares the maximum % RR of the proposed method with other [23], [24], [25] techniques. It is observed that the proposed algorithm achieve better results than other methods.

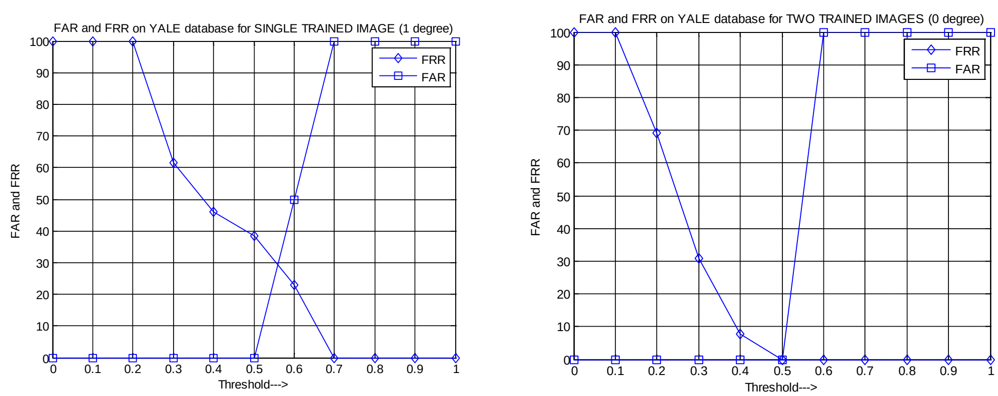
(ii) *Kinect database.* The images of 52 persons used to test the algorithm, images of 29 persons are used as database, and remaining 23 persons are used for testing purpose. For FRR computation, an image of a person which is not in database is used i.e. each person`s 9th image. FAR is computed by using 5th image of 23 out of database persons. Performance is tested for single and double trained images rotated in +/-1^0, +/-2^0, +/-3^0, +/-4^0 and +/-5^0. The rotation invariance property is observed for 0^0 and +/-1^0 angles for single trained image case as depicted in Table 7 and the maximum %RR for single and two trained images are 55.1 and 93.1 respectively. Figure 7 shows the plot of Threshold in X-axis with FAR and FRR in Y-axis for (a) Single and (b) Double trained images with 0^0 rotation. Figure 8 consolidates the maximum % RR rotated in different angles on Kinect database for single and double trained images. An average % RR of 50.3 and 79.7 is obtained respectively for single and double trained images for rotation angles mentioned in Figure 8. Table 8 compares the maximum % RR of the proposed method with the other [26], method. It is observed that the proposed algorithm achieve better results than the method compared.

Table 5 : Performance on Yale database for Single and Double Trained images

Threshold	Single Trained Image +/-1^0, -2^0 , +/- 3^0, +/- 4^0 Rotation			Double Trained Images 0^0, 1^0, 2^0 , 3^0, 4^0 Rotation		
	% FRR	% FAR	% RR	% FRR	% FAR	% RR
0.0	100	0	0	100	0	0
0.1	100	0	0	100	0	0
0.2	100	0	0	69.2	0	30.7
0.3	61.5	0	30.7	30.7	0	69.2
0.4	46.1	0	46.1	7.6	0	92.3
0.5	38.4	0	46.1	0	0	92.3
0.6	23	50	53.8	0	100	92.3
0.7	0	100	53.8	0	100	92.3
0.8	0	100	53.8	0	100	92.3
0.9	0	100	53.8	0	100	92.3
1.0	0	100	53.8	0	100	92.3

Table 6 : Comparison of Maximum % RR with other methods on Yale database

Method	Maximum % RR
ALBP +BCD [23]	71.9
WM(2D)2PCA [24]	80.77
GABOR +DTW [25]	90.67
Proposed FR DMF model	92.3



(a) (b)

Fig. 5 : Threshold versus FAR & FRR on Yale database for (a) One & (b) Two trained –images

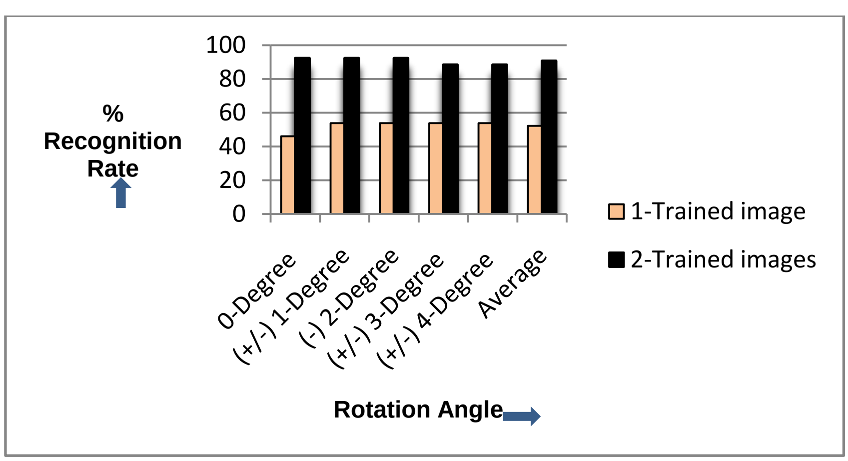


Fig. 6 : Comparison of Maximum % RR for Different Rotation Angles on Yale database

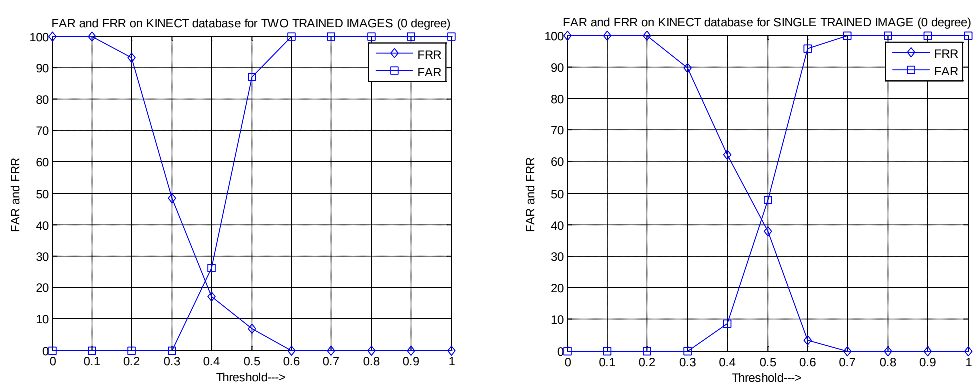
(iii) *Indian database* of 50 persons are considered to test the algorithm, images of 23 persons are used as database, and remaining 27 persons are used for testing purpose. Other than the image of a person in database is used for FRR computation i.e. Each person`s 11^{th} image and FAR is computed by using 5^{th} image of 27 persons. Performance is tested for single and double trained images rotated in +/-1^0, +/-2^0, +/-3^0, +/-4^0 and +/-5^0 on Indian database. From Table 9 the maximum % RR for single and two trained images are 55.1 and 93.1 respectively with no rotation. Figure 9 shows the plot of Threshold in X-axis with FAR and FRR in Y-axis for (a) Single and (b) Double trained images with 0^0 rotation. Figure 10 consolidates the maximum % RR rotated in different angles on Indian database for single and double trained images. An average % RR of 76.5 and 78.2 is obtained respectively for single and double trained images for rotation angles depicted in Figure 10. Table 10 compares the maximum % RR of the proposed method with the other [27], [28] method. It is observed that the proposed algorithm achieve better results than the method compared.

Table 7: Performance on Kinect database for Single and Double Trained images

Threshold	Single Trained Image 0^0 , +/- 1^0 Rotation			Double Trained Images 0^0 Rotation		
	% FRR	% FAR	% RR	% FRR	% FAR	% RR
0.0	100	0	0	100	0	0
0.1	100	0	0	100	0	0
0.2	100	0	0	93.1	0	6.8
0.3	89.6	0	10.3	48.2	0	51.7
0.4	62	8.6	31	17.2	26	82.7
0.5	37.9	47.8	37.9	6.8	86.9	89.6
0.6	3.4	95.6	55.1	0	100	93.1
0.7	0	100	55.1	0	100	93.1
0.8	0	100	55.1	0	100	93.1
0.9	0	100	55.1	0	100	93.1
1.0	0	100	55.1	0	100	93.1

Table 8 : Comparison of Maximum % RR with other method on Kinect database

Method	**Maximum % RR**
HOG – 100 Samples Case [26]	86
Proposed FR DMF model	93.1



(a) (b)

Fig. 7 : Threshold versus FAR & FRR on Kinect database for (a) One & (b) Two trained images

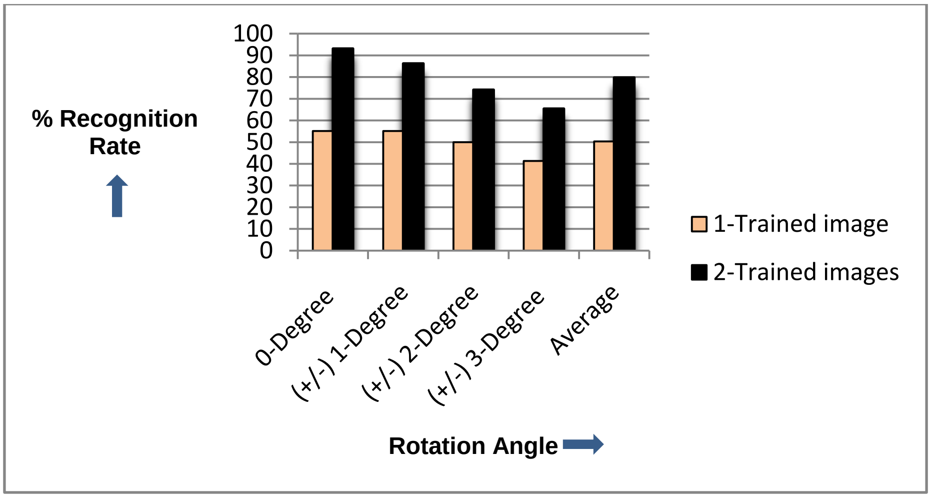


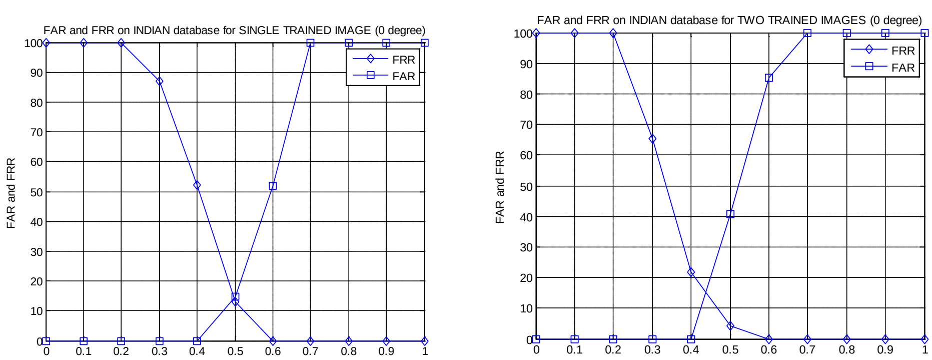
Fig. 8: Comparison of Maximum % RR for Different Rotation Angles on Kinect database

Table 9 : Performance on Indian database for Single and Double Trained images

Threshold	Single Trained Image 0^0 Rotation			Double Trained Images 0^0 Rotation		
	% FRR	% FAR	% RR	% FRR	% FAR	% RR
0.0	100	0	0	100	0	0
0.1	100	0	0	100	0	0
0.2	100	0	0	100	0	0
0.3	86.9	0	13	65.2	0	34.7
0.4	52.1	0	43.4	21.7	0	78.2
0.5	13	14.8	82.6	4.3	40.7	91.3
0.6	0	51.8	95.6	0	85.1	95.6
0.7	0	100	95.6	0	100	95.6
0.8	0	100	95.6	0	100	95.6
0.9	0	100	95.6	0	100	95.6
1.0	0	100	95.6	0	100	95.6

Table 10 : Comparison of Maximum % RR with other method on Indian database

Method	Maximum % RR
MB-LBP [27]	79.2
Six- Morphological Operations case [28]	94.2
Proposed FR DMF model	95.6



(a) (b)

Fig. 9: Threshold versus FAR & FRR on Indian database for (a) One & (b) Two trained images

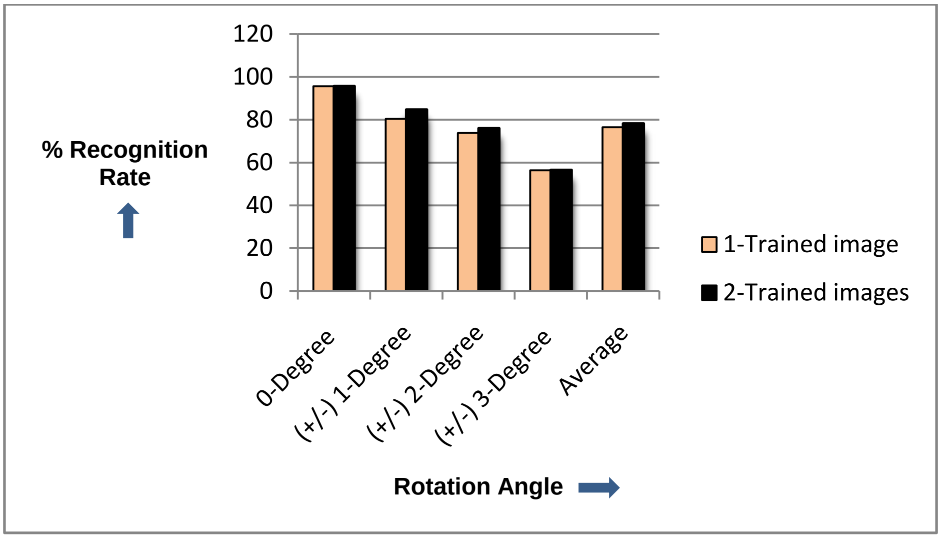


Fig. 10 : Comparison of Maximum % RR for Different Rotation Angles on Indian database

The results are improved based on following Reasons; Robert's operator used in preprocessing to detect edges is simple and efficient in extracting high frequency unique details of the image. The robustness of matrix 2-norm, infinite norm, trace and rank features for different rotations (from Table 2) contributes for improvement in performance. Fusion of matrix and diagonal features is also a key factor in boosting the recognition accuracy.

VI. Conclusion

Recognizing a person using fewer acquired images is a thrust area for research and rotation parameter attracts considerably in realtime applications. In this paper, the face recognition method proposed is simple and efficient using fewer database images. Image rotation is performed only on test images. Preprocessing uses an edge detection method for cropping facial part. All preprocessed images are divided into one hundred matrices of 5*5 size each. For each 5*5 part of image, matrix 2-norm, infinite norm, trace and rank are computed. These four matrix coefficients are respectively averaged to yield one hundred matrix features. In addition to this, all preprocessed images are transformed in spatial domain using a 3*3 mask. Another one hundred diagonal features are obtained by adding both principal and secondary diagonal elements of transformed matrix. Final features are computed by fusing matrix and diagonal features. Comparision of database and query image features is made using Euclidian distance measure. The results on Yale, Kinect, and Indian face databses are considerably improved over other existing methods.

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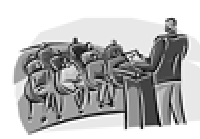

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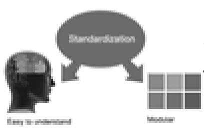

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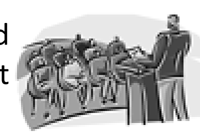

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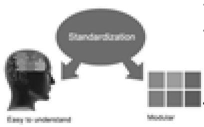

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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
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