Software Proposal Document for Thermal Face Recognition project

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Abstract

The main idea of this project is to study Face recognition using thermal signatures of the human person, by detecting the face of the person, extracting some features from it and finally classifying the face to to tell whose face it is. Many algorithms have been used before but we have not settled yet on specified algorithms to use for the project. We have datasets that have been used and tested before, we will test the algorithms on different databases to come up with the best recognition rate.

1 Introduction

1.1 Background

Face recognition has been rapidly spread in the last decades, it has been used in many real world applications such as security, forensics, crimes, etc.. However, classic face recognition faced many problems in detecting and recognizing the face in low light, head poses and expressions [1]. Thermal images is currently used to solve these problems [2],[3] , but it has not been used too much because of its high cost and its sensors and equipment were not available much. Lately, due to the advance in technology, applying the concept of thermal imaging became easier because of the advance of infrared imaging and technology and the availability of its equipment.

1.2 Motivation

- Implementing the method on different poses and other benchmark databases [6].

- Reducing environmental distractions [3].

- Using one of the parallel processing techniques to increase the processing rate, thus making our model more suitable for the real time application [1].

- Working on the implementation of the system on the four 1.2 GHz processors to optimize the recognizing speed [17].

- Treating detection of facial expression as a separate problem. Also considering pose changes of subject for their experiments in future.

- Temperature variation may create different thermal pattern of the same face image.

1.3 Problem Definitions

As mentioned, classic face recognition has faced many problems due to many variables such as facial expressions, head poses and illumination invariant. So thermal face recognition was employed to contribute solving these problems. Similar works had been done before. And they also faced some problems in different poses of the head, in the recognition rate, size of images in the database and also the processing rate of the recognition.

2 Project Description

Show down with a figure the proposed system.

2.1 Objective

The objective of the project is to develop a system that recognizes the faces using thermal signatures of the person, because it has many advantages to the classic face recognition like light problems and head poses. Working on improving the recognition rate of the thermal image. Trying to have a bigger database to have more images to be compared with or improving the recognition processing.

2.2 Scope

Trying many algorithms for features extraction and classifying. Testing these algorithms and calculating the recognition rate, size of database and the processing rate of the captured images. Also trying hybrid systems to use more than one algorithm or combining them to have a better recognition rate and speed. Trying more than one database as well to calculate the best result. And if we failed in this, using thermal camera to capture the images will be the alternative method.

2.3 Project Overview

Many algorithms have been used before for this problem. We do not have specified algorithms to use for our proposed model, but there are a list of algorithms

that we have in mind that we are going to test as mentioned in the scope. For example; (SFTA), (CNN), (ANN) for features extraction. (PCA), (LDA) for dimensionality reduction.

3 Similar System Information

1- Thermal face recognition using convolutional neural network, IEE 2016. [7]

Mentioning that similar work used some of the traditional thermal recognition methods which requires more efforts from human to select and extract features, they faced some problems like the improvement of recognition rate, the methods were not capable enough to describe the details; or even traditional methods that have some shortcomings such as the complicated process. Alternative method Convolutional

Neural Network(CNN) is a deep learning algorithm, it has been proposed because it can automatically learn new features from raw data, also it combines features extraction and classifying into one step that can reduce the workload for the humans. In a multi-layer neural network architecture, each node undergoes some calculations and serves the next node with them, each node's value is relevant to its previous node.

In Convolutional Neural network, is can optimize the normal neural network structure (9 layers). To test the CNN model, The RGB-D-T Face Database was used, its images were collected from different types of cameras. Images were taken of 51 students with respect to three main aspects; head rotation, facial expression and illumination variation. So 100 images for 51 students with 3 aspects, there are 15300 (51x3xlOO) images in the database to be trained and tested with.(((The proposed CNN has nine layers.

Convolution layer 1 employs 64 different convolution kernels whose output image is 56x56 in size. The output data of max pooling layer 1 are decreased into 28x28, which undertakes down-sampling. The fourth layer is mainly to perform normalization, which is advantageous to the data in the form of image. Then, the data are convoluted and pooled twice, whose dimension and size become 128 and 7x7. Finally, the data are grouped into 51 class. The structure and the output size of each layer are summarized in Table I.)))

Layer	*Output*
Images data	112×112
Convolution layer 1	64×56×56
Pooling layer 1	64×28×28
Norm layer1	64×28×28
Convolution layer 2	128×28×28
Pooling layer 2	128×14×14
Convolution layer 3	128×14×14
Pooling layer 3	128×7×7
Classifier layer	51×1×1

Experimental results had been done and compared with three competitive algorithms which are; LBP, HOG, Moment Invariant. It showed that with due to respect of the three previously mentioned aspects, head rotation affects the most in the recognition rate of the images, whereas illumination variation has the least effect of the three on the rate. In table II, a comparison has been done to show the results, and it shows that CNN outperforms the three other algorithms in the recognition rate.

	Head Rotation	*Expression*	*illumination*
LBP	79.33	96.27	98.35
Moment Invariant	59.37	91.76	94.51
HOG	90.27	98.78	99.18
Our Method	98.00	99.40	100.00

This paper is based on work that is very similar to our project idea, and we think comparing our work to theirs and having them as a reference will be very helpful for us.

2- Human Thermal Face Recognition Based on Random Linear Oracle (RLO) Ensembles[1]

They started talking about classic face recognition where there has been remarkable progress in it. However, they faced many problems like image variation due to many differences in head positions, expressions and poses. So infrared image recognition has been employed to solve this problem, at the beginning it has not received much attention due to many limitations, but recently these limitations are being broken one by one and they can solve the problems classic face recognition faced. Mentioning that every person has a unique thermal

signature for him depending on temperature and characteristics.

Improving the recognition rate based on Terravic Facial IR Database was their main motivation to work on. Similar works have been done before, in [8], PCA has been used for dimensionality reduction, and then two different classifiers have been used to identify the image. Based on Terravic Facial IR Database, recognition rate reached 94.11 percent. In [8], Wavelet transform has been used for features extraction, then providing them to the classifiers. Based on Terravic Facial IR Database, recognition rate has reached 93 percent.

This paper proposed an approach with two variants based on Random Linear Oracle Ensembles (RLO). Segmentation based Fractal Analysis(SFTA) algorithm was used for features extraction, then RLO ensembles was used to recognize the face from its thermal image. For the dimensionality reduction, one variant (SFTALDA-RLO) was used the technique of Linear Discriminant Analysis (LDA) while the other variant (SFTA-PCA-RLO) was used the Principal Component Analysis (PCA).

The proposed model consists of two phases; training phase and testing phase. In the training phase, the training data or images are collected, then (SFTA) algorithm is used to extract features from every one of them, then PCA and LDA are used for dimensionality reduction which are used to build the RLO model, which is later on used in the testing phase. In the testing face, the unknown or test image is captured, extracting features from it using (SFTA), then project the extracted features from the dimensioned vectors from the training phase and match them with the results.

Experimental results, the Terravic Facial IR Database was used to evaluate our two variants. The dataset set consists of 20 classes with greyscale images (360 x 240) and each class represents one person. In this paper, we have used 17 classes as three classes were corrupted. For each class, 200 grey-scale images were used.

3- Real-Time Efficient Parallel Thermal and Visual Face Recognition Fusion [17]

Most of the decision fusion techniques are computationally expensive, same as Gabor filter since it requires high computational requirements, So this paper decided to use a parallel solution which is fast and efficient.

They started discussing Gabor Filter For face recognition, One of the most successful recognition methods is 2-D Gabor Filter[10] which states :

$$R1 = x\cos(\theta) + y\sin(\theta)$$
$$R2 = -x\sin(\theta) + y\cos(\theta)$$

$$R(X,Y,\theta,\lambda) = \sum_{x=-X}^{N-X-1}\sum_{y=-Y}^{M-Y-1} I(X+x,Y+y)f(x,y,\theta,\lambda)$$

They chose the feature point in a particular window of size SxT where $S = N/\sqrt{W}$ and $T = M/\sqrt{W}$

Architecture of Visual, Thermal and Fuse data Fusion. Each of them has four main processing sub-modules :

- o Feature value calculation
- o Feature vector selection
- o Similarity calculation
- o Decision fusion

Decision Fusion Architectures :

They used a much flexible decision fusion as proposed in [11] for the combination of Visual, Thermal and Data Fused Face Recognition. Figure 1 shows Decision Fusion Face Recognition Architecture.

The below table shows that the accuracy of decision fusion is greater than without any fusion:

Input Type / Accuracy of Resolution	21x30	37x49
Thermal	38%	38.6%
Visual	63%	74.38%
Decision Fusion (Visual and Thermal)	86%	97%
Decision Fusion (Visual, Thermal and Fused Data)	97.11%	98.6%

Parallel Architecture has its own Resource Requirements, for example a parallel code that runs in 1 hour on 3 processors actually uses 3 hours of CPU time, also memory for parallel recognition is bigger than normal one, moving to its benefits, Parallel Face Recognition speedups performance to three times that of sequential face recognition , also it's portability since it can be run on

LAN and no special arrangements would be required.

DATABASE

Experiments were performed on database called Equinox includes 24 persons, each has 3 images (Thermal, visual and fused) with frontal illumination [12].

4-Fusion Based Approach for Thermal and Visible Face Recognition underPose and Expressivity Variation [18]

In this paper the researchers investigate the combined advantages of thermal and visible face recognition on a Principal Component Analysis (PCA) induced feature space. Recognition is done with k-nearest classification.

The basic PCA approach to Face Recognition is often used for data analysis, it offers solution of reducing a complex data to set a lower dimensional one. It firstly explored by Turk and Pentland[13]. Goal of PCA is to derive another matrix P which will describe linear transformation.

We compute matrix as follow:

$$M = \frac{1}{S}\sum_{i=1}^{S} X_i \ .$$

Then Subtract the mean face:

$$H_i = X_i - M \ .$$

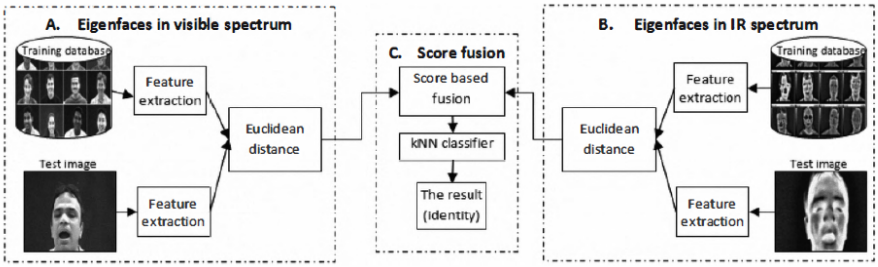
Compute the covariance:

$$C_A = \frac{1}{S-1} AA^T \ .$$

As for Classification, they used K-NN Classifier with Euclidean distance, to build it they needed to define the number of classes C, to form a labeled training set of N samples. The algorithm need to follow those steps:

a) Compute the distances for each prototype.
b) Sort the distances increasingly.
c) Assign to W (vector) most frequent from the class sort array y1,y2,y3,..

Figure below shows the fusion scheme (A) PCA-based face recognition in visible spectrum; (B) PCA-based face recognition in IR spectrum(C) Score fusion of (A) and (B).



A- Computing the Eigenfaces from the visible images.
B- Computing the Eigenfaces from the IR Thermal Images.
C- The Score Fusion Scheme.

DATABASE

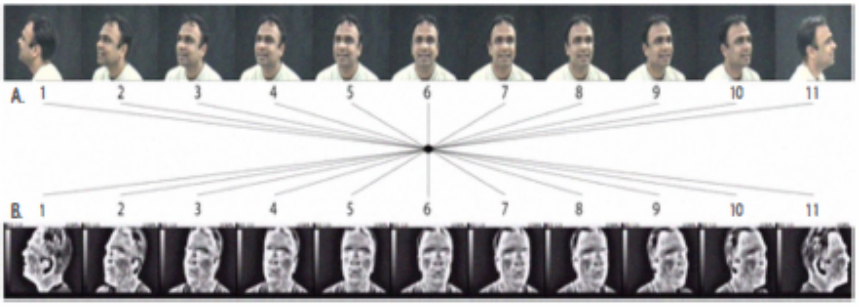
As for database, they used 3 databases

a) OTCBVS benchmark[14]
b) Notre IR Database [15]
c) Equinox IR Database [16]

For training Sets they used Notre IR Database, as for Testing they used Equinox IR Database, but for their experiments they used OCTBVS benchmark which contains 4228 pairs of visible and IR Thermal Images

They used for training set a total of 12 nearly frontal images for each subject 6 images in IR Spectrum and 6 images in visible spectrum, for each spectrum there are 3 images under the "surprised" and 3 under "Laughing", and 11 positions for each type of acquisition as in Fig. 3 below)

This figure is an example of an subject under pose variation: Visible Spectrum images and IR Thermal images



RESULTS AND TESTS

They ended up that recognition for the IR Spectrum is lower than the visible Spectrum, they also saw that for the 1-NN Classification had a superior results in all test that achieved 100 percent recognition in some tests(test 4). Moving on , the recognition rate for the classical PCA-base approach is as poor as 69.10 percent and their fusion based approach improves the recognition rate with almost 6percent. So at last their fusion based approach exceeds the individual performance of the systems with almost 10 percent.

Below Tables are the results for 1 ,3 ,5 and 7 k-NN Classifier with the 3 views (Visible , IR and Bimodal)

1-NN

	Visible	IR	Bimodal
Test 1 rates(%)	91.66	73.80	96.42
Test 2 rates(%)	95.08	87.05	98.21
Test 3 rates(%)	89.28	62.50	92.85
Test 4 rates(%)	99.10	92.85	100
Test 5 rates(%)	69.10	53.72	74.85
Test 6 rates(%)	75.89	56.25	82.73

So, from those tables there is an obvious result which is using 1-NN classifier in Bimodal has the highest and best rates in recognition.

5- Thermal human face recognition based on GappyPCA [19]

They have proposed a Gappy-PCA thermal human face recognition technique for frontal face only. The results obtained on testing sets about 98.61 Percent correct recognition

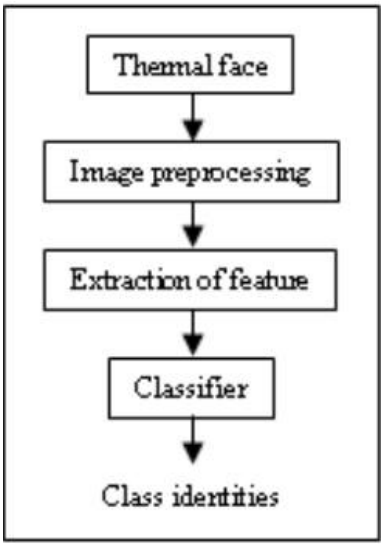
- Researches use infrared images for face recognition until they come up with better system performance because the use of thermal face images is better than visual images.

1. Infrared camera captures energy from the object surface
2. Thermal images do not depend on illumination
3. Face detection, location and segmentation are easier and more reliable for thermal face images then their visual images

- The problem can be classified into two categories:

1. Feature based : find geometrical features from the face
2. Holistic methods : Judge the global properties of the human face pattern

Proposed Approach



- Preprocessing : they covert each color images into grayscale images and then convert the grayscale images into their corresponding binary counterparts (Connected component labeling algorithm: used to extract the largest component from the binary image) Then they used Bresenham ellipse drawing algorithm to crop the human face in elliptical shape

Principal Component Analysis (PCA) is used in the problem of contaminated pixel. But it can't restore the missing information so they use GPCA approach to store the statistical information that is missing in the PCA

- Extraction of features: In every gray scale image, each pixel is represented by 8 bits; the range of intensity value is 0 to 255 Each image of the images is transformed into horizontal vector to get the "n-dimensional vector"

- Classification: Linear regression based classifier (LRC) is used for classification, LRC has less limitation than the artificial neural network (ANN) and support vector machine (SVM) LRC is simple and use easy calculations and faster than the other algorithms

EXPERIMENT AND RESULTS

FLIR 7 CAMERA is used in the experiment. 12 Frontal images are taken in each person Image size 112*92

- Experimental process divided into two ways :

    1. Simple approach features are extracted before the restoration process, total images are testes using 2-Flod and 3-Flod
    2. GPCA based approach is used to get the better performance and to restore missing thermal pattern

- GPCA gives better result compared to the simple approach under both the 2-flod and 3-flod The highest percentage of recognition rate is 98.61 under 2-flod cross validation

Future Work : In future, authors will treat detection of facial expression as a separate problem. Authors will also consider pose changes of subject for their experiments in future. Temperature variation may create different thermal pattern of the same face image

6- Thermal infrared face recognition based on lattice computing (LC) techniques [20]

- They proposed a human face recognition system that carries out four information-processing tasks:

    1. Image acquisition : Carried out by the camera hardware
    2. Face localization : Carries out stable robust face localization in the sense that is clearly separates the face from the background (Viola-Jones face detector or Alternative face detector)
    3. Feature extraction : Carried out using orthogonal moments

4. Classification : Carried out using techniques from the lattice computing framework (LC)

- In Face localization they used five methods

1. image is converted to Gray scale
2. Image Binarization : They convert the gray scale image to a binary image to get all the useful face information
3. Morphological Opening and Center of Mass Computation
4. Ellipse Masking
5. Face Cropping

They carried out feature extraction by computing orthogonal moments (ZMs And TMs) on the cropped image with a capacity to encode image content with minimum redundancy

They used MATLAB platform to implement their software and "The Terravic Facial IR benchmark Dataset", The database includes images of 20 persons . 700 images for the first 10 persons (total 700 images) 690 of them were used for testing and the other 10 were used in training Local Binary Patterns (LBP) ins used for the temperature distribution the images. Their best results were 95.43 Percent while using LC-MDC Classifier and TMs Feature as explained in table below.

Method	Features Type	Classifier Type	Recognition Rate (%)
[30]	CoG	MDC	85%
[28]	LBP & PCA Wavelets & PCA	MDC NNs	94.11%
Proposed	TMs	LC-MDC	**95.43%**

3.1 Similar System Description

There are many efforts that had been done in thermal face recognition, but we have limited the similar systems to these two [1],[7] because they are the closest efforts to our project.

In [1], the paper proposed a model based on thermal face recognition based on Segmentation based Fractal Texture Analysis (SFTA) to extract features from the faces, and Random Linear Oracle(LRO) to recognize the face from its thermal image.

In [7], they proposed a Convolutional Neural Network(CNN) method for thermal face recognition with respect to head rotation, expressions, illumination variation. And compared with traditional recognition methods, the proposed system can produce the best recognition results and it suggests that this method is a very promising one that can be used in under extreme conditions and still produce the best result.

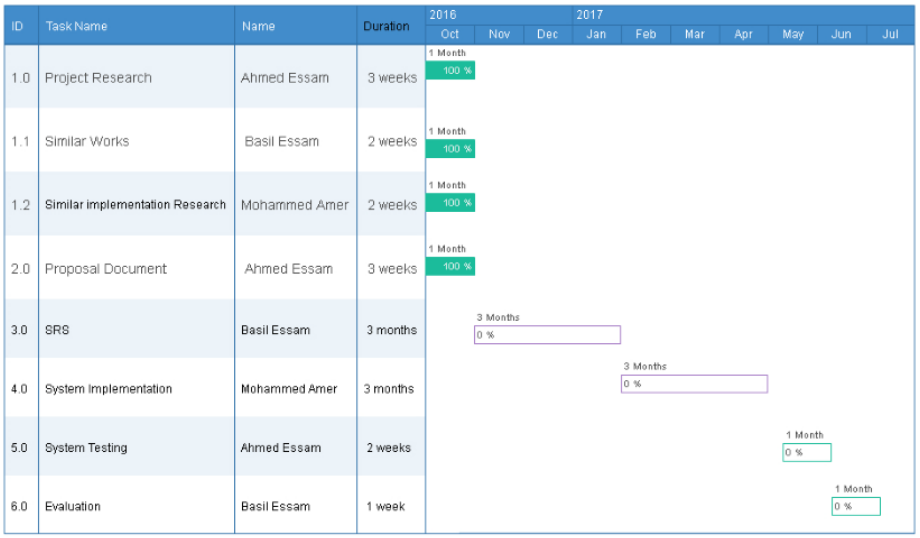
3.2 Comparison with Proposed Project

	Human Thermal Face Recognition Based on Random Linear Oracle(RLO) Ensembles[1]	**Thermal Human Face Recognition Based on Gappy-PCA[2]**	**Real Time Efficient Parallel Thermal Face Recognition[3]**	**FBA for Thermal & Visible Face Recognition under Pose and Expressivity Variation[4]**	**Our Proposed Method**
Algorithms	- (SFTA) Features extraction - (PCA,LDA) Dimensions reduction - (RLO) Recognize thermal image	- (PCA) - (GPCA) Store the statistical information that is missing in the PCA	Parallel Fusion (Gabor Filter)	- (PCA) - (KNN) Classifier	- Features Extraction: (SFTA, PCA, CNN, ...) - Dimensionality Reduction: (PCA, LDA, ...) - Classification: (RLO, KNN, CNN, ...)
Database	Trerravic Facial IR Database	Their Own Database(12 frontal 112*92 images)	Equinox Face Database	- OTCBVS benchmark - Notre IR Database - Equinox IR Database	(Terravic Facial IR DB, OCTBVS, Equinox IR DB, ...)
Best Recognition Rate	94.12%	98.61%	98.6%	1-NN : 90.84% 3-NN: 87.18% 5-NN: 81.76% 7-NN: 78.86%	–

4 Project Management and Deliverables

4.1 Tasks and Time Plan

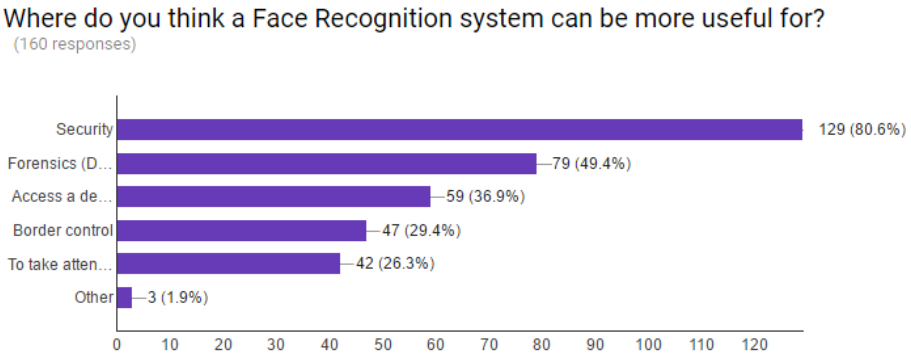
ID	Task Name	Name	Duration
1.0	Project Research	Ahmed Essam	3 weeks
1.1	Similar Works	Basil Essam	2 weeks
1.2	Similar implementation Research	Mohammed Amer	2 weeks
2.0	Proposal Document	Ahmed Essam	3 weeks
3.0	SRS	Basil Essam	3 months
4.0	System Implementation	Mohammed Amer	3 months
5.0	System Testing	Ahmed Essam	2 weeks
6.0	Evaluation	Basil Essam	1 week



4.2 Budget and Resource Costs

In case of buying a thermal camera, its cost is around 200USD-350USD.

4.3 Supportive Documents



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