ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

3D Object Recognition for Automated billing in a Supermarket using Hybrid PCA-SIFT-FREAK Algorithm

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ABSTRACT:3D Object recognition systems can be very helpful for an automated billing system with minimum human involvement. Many object recognition algorithms have been developed performance of which varies in terms of accuracy, computation time etc. A practical computer vision system for automated billing application must be simple with very good accuracy as a mismatch will lead to wrong billing having huge economic implication. SIFT is a floating point descriptor with good accuracy but high memory requirement. PCA-SIFT is a modified version of SIFT with reduced dimensionality. FREAK is a binary descriptor which requires very less memory space, reduced extraction and matching time but lesser accuracy than SIFT. In present work, a Hybrid PCA-SIFT-FREAK algorithm is proposed which attempts to find a balance between accuracy and memory. Comparative study of the performance parameters like recognition rate, computation time, memory requirement, confusion matrix is done for SIFT, PCA-SIFT and Hybrid algorithm. A real time application for automated billing is developed in which customer can bill his purchase using a Graphical User Interface on a computer screen linked to a camera. The system is also developed for simultaneous detection of multiple objects offering advantage over barcode based billing system. The computation time for 25 objects are 824s, 278s, 300s using SIFT, PCA-SIFT and Hybrid algorithm respectively. This can be reduced significantly using commercial purpose computers with good processing capability. The size of the database in MB (CSV files containing the descriptors is 80.1MB, 61.2MB, 72.2MB using SIFT, PCA-SIFT and Hybrid algorithm respectively. The recognition rate for a small dataset of 25 objects is 88%, 96% and 100% for SIFT, PCA-SIFT and Hybrid algorithm respectively. The real time system using the hybrid approach can be good trade-off between parameters for an application like billing system where accuracy of recognition is very crucial for correct billing.

KEYWORDS: Barcode, Object Recognition, SIFT

I.INTRODUCTION

Barcodes are widely used in many grocery supermarkets like Big Bazar, Easy Day for billing and statement generation.Check-out counters use laser bar-code readers in such stores but the space between the sensor and the object should be nearly zero when the reader is applied. The billing personnel have to manipulate either the reader or the objects. This makes the task tedious for the human worker. Each object has to be scanned individually taking much time and making the task monotonous for the billing personnelespecially in big stores where hundreds of customers turn up in a day and thousands of objects have to be scanned in a day.In the modern era, the people have more income to spend and lesser time to spare, so they generally choose supermarkets for grocery and other shopping rather than local shops. Actually the customer is free to choose products from huge available varieties which attract the large customers mainly in big cities so long queues of customers are seen at these stores. In many cases, the barcode is either damaged or there may be problem in reading it due to lighting effects, occlusion, low resolution etc.A bar code based billing system is also costly as it requires bar coding of all products. The world is moving towards an era of automation and human capital is a great asset which should be used in more intellectual works rather than manual, monotonous works. The advancements in technology have led to high speed computers with excellent processors and storage capacity. The concepts of Robotics, 3D Object recognition can be used to develop an application for real time automated billing to ease laborious human work. For the purpose of automation, the human operator needs to be

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Vol. 6, Issue 7, July 2017

removed from the process. Computer vision [2] based systems could be developed and deployed for such an automated billing application where minimum human interference and lesser wait time is required leading to customer satisfaction. The recognition in tangled real-world scenes needs to be unaffected bynearby tangle, fractional obstruction, orientation change, scale change. Local descriptors [3] are generally engaged in various real-world applications like image retrieval [4] and object recognition [5] because they are resistant to fractional obstructions, relatively unaffected to deviations in view and can be computed capably. There are two things to be kept in mind while using local descriptors. First, the interest point in position and scale must be chosen to safeguard only those points that are most probable to remain stable over transformations. Second, the interest point descriptor must be built distinctive, concise, and invariant over transformations. Thus,the main steps in object recognition are computation of local interest points, computation of descriptors and indexing/matching- In detection, some operators are applied to find typical key points [6] during the feature detection stage to match well in other images. In description, the detected features are termed on the basis of the neighbour pixels around it during the feature description stage. In matching [7], each demanded feature is matched to the similar features with the referred one during this stage. Various types of local feature detector and descriptor [12] have been developed but different recognition rates, efficiency, computation times, memory [8] requirements are obtained by using various descriptors interest point algorithms for detection, description and matching. The challenge is to find the algorithms which are suitable for theautomated billing applicationand finding the balance between various parameters to best suit the application. Corner Detectors [13] detect corners which are defined as ajuncture of two or more edges. These are Harris Key points, FAST [14], Moravec, Harris Laplace, Harris Affine [15] , SUSAN and BRISK, ORB etc. Blob Detectors detect a blob which is an image pattern that is dissimilar from its immediate neighbourhood in terms of intensity, colour and texture. These are of various types like Difference of Gaussian (DoG), Determinant of Hessian, Fast Hessian etc. Floating-point descriptor is a feature vector with varying in dimension like 128-dimensional and 64-dimensional vectors for SIFT and SURF [16] descriptors, respectively. Others are C-SIFT.ASIFT, PCA-SIFT etc. These have good discriminative power [17] but occupy large memory space. Binary interest point descriptors [18] like BRIEF, ORB, BRISK, FREAK [19] contain a string consisting of 0 and 1 and require less memory. SIFT features are created by discovering key points in an image. After resizing and RGB to gray conversion, differentGaussian [4] octaves on the input image are calculated and then the difference is calculated of nearby octave layers. Fordetecting key point, a pixel is considered and it is compared with all the nearby pixels in the upper and lower layer of DoGto find maxima and minima. For each key point a canonical orientation vector [7] is calculated and a 128 dimensional SIFT feature vector is calculated. SIFT key points do not vary with scale, rotation and changes in perspective which makes it an ideal descriptor for object recognition tasks. However, relatively high dimensionality is a general problem of SIFT making it more memory exhaustive especially for large datasets. An extended form of SIFT is PCA-SIFT [18] which addresses this problem in SIFT. Principal component analysis (PCA) is done to reduce dimension. PCA-SIFT uses the SIFT [20] source code with changes in only the description stage. It pre-computes an Eigen space and the gradient images vector of local patches is projected to derive a compact feature vector which is of 20 dimensions only. The Euclidean distance can be used as matching algorithm to ascertainif the two vectors represent the same key point in two images. FREAK [22] is a binary key descriptor motivated from the human optical system. How the image is transferred to the brain is explained and understood by the neuroscience. With increase in radial distance in retina [23] from the foveola, its size and dendritic field increases. Higher resolution is captured in the fovea whereas a lower resolution in the perifoveal. Vision algorithms need to run on mobile devices with low computing power and memory capacity. FREAK being a binary descriptor requires lesser memory. In FREAK, sampling pattern is retinal and the sampling grid is circular with higher density of points near the centre, the receptive fields are overlapping. Sampling points are smoothed with a Gaussian kernel to become less delicate to noise ratio. At this point, the sampling grid can be distribution of receptive fields in actual retinas. The compared pairs are selected by maximizing variance of the pairs, and taking pairs that are not correlated and 128 pairs are defined. The intensity value comparison within pairs is gathered by a binary string.

II. METHODOLOGY

Fig. 1 shows the overall methodology by using PCA-SIFT-FREAK Hybrid approach combing a floating point and binary descriptor. Many image and object recognition algorithms have been developed but they may suffer from problems like poor accuracy and long processing time for pre-stored feature patterns, and tedious gradation and image alteration. That is why practical deployment of advanced systems is difficult.While floating point descriptors have good

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Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

discriminative power, they require larger memory and computation time. Binary descriptors [9] on the other hand require lesser memory and time but lesser accuracy in many cases. Keeping in mind the pros and cons of a binary and floating point descriptor [24] a hybrid approach which does fusion of features of PCA-SIFT- FREAK algorithm is developed.

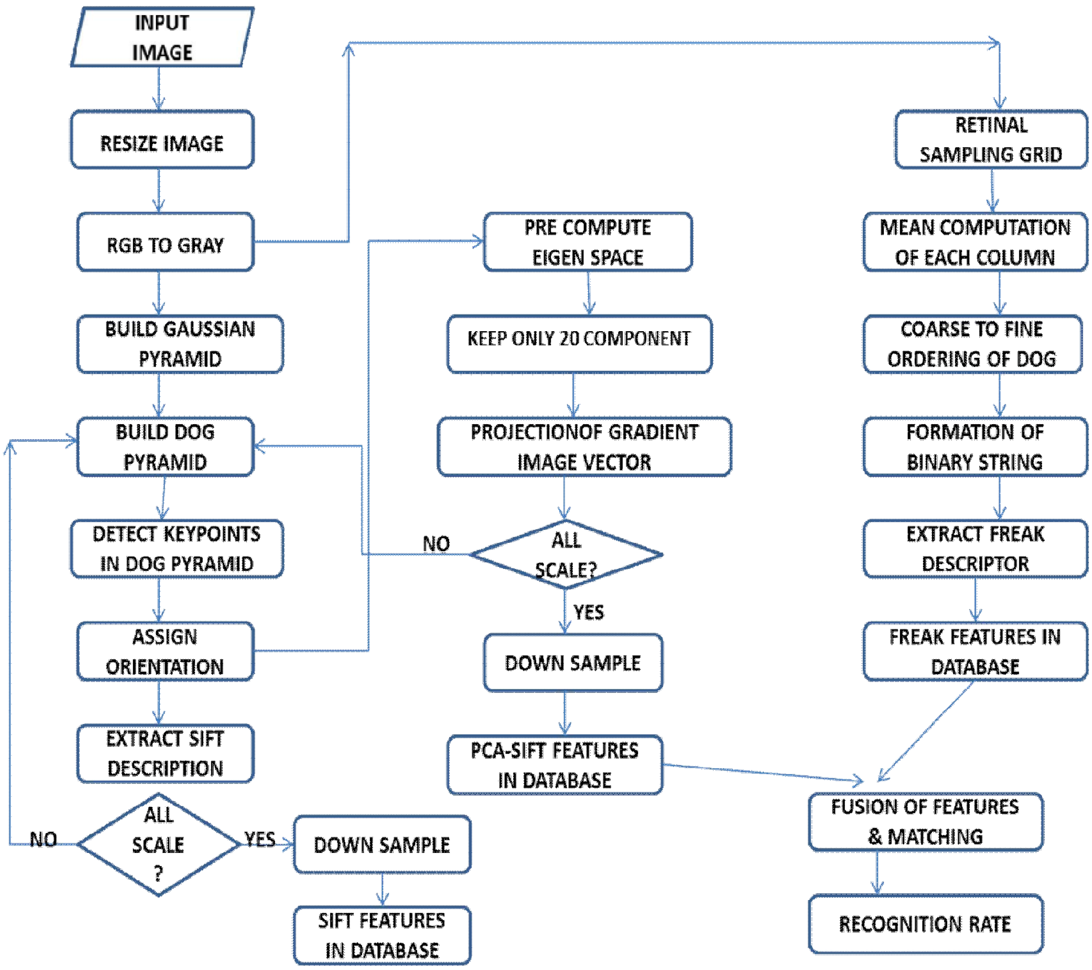

Fig. 1 PCA-SIFT-FREAK Hybrid Algorithm

The image is resized and is converted from RGB to gray. Gaussian pyramid is formed. Then the difference of nearby octaves is calculated forming DoG Pyramid and the key points are detected by finding maxima and minima in it.An orientation vector is calculated for each key point. Thus the steps of SIFT are followed up to this stage. Eigen space and projection oflocal patches gradient images is performedto derive a compact PCA-SIFT feature vector by down sampling. The FREAK feature descriptor [25] is calculated for the same grayscale image. After obtaining the PCA-SIFT and FREAK features, the key points of both are taken together so that no important key points are missed.

Hardware used: Real-time implementation is done using the Laptop and Camera
Laptop Specifications: Dell Inspiron 15, Processor Intel (R) Core (TM) i5-5200U, 2.2 GHz
Camera Specifications: Logitech HD 720p

Software used: MATLAB version 2017

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Vol. 6, Issue 7, July 2017

Toolbox used: MATLAB image processing toolbox, MATLAB Image acquisition toolbox, MATLAB GUI Toolbox

III.RESULTS AND DISCUSSION

All the steps i.e. database creation, testing stage, training stage, comparative results of the algorithms and real time implementation results are presented.

1.Database creation: Fig. 2 shows the custom database sample images. Creation of customized database is done by clicking pictures of objects. 5 images of a single object is taken by varying the scale,orientation A database of 25 objects is created. These objects are those typically found in a supermarket environment.

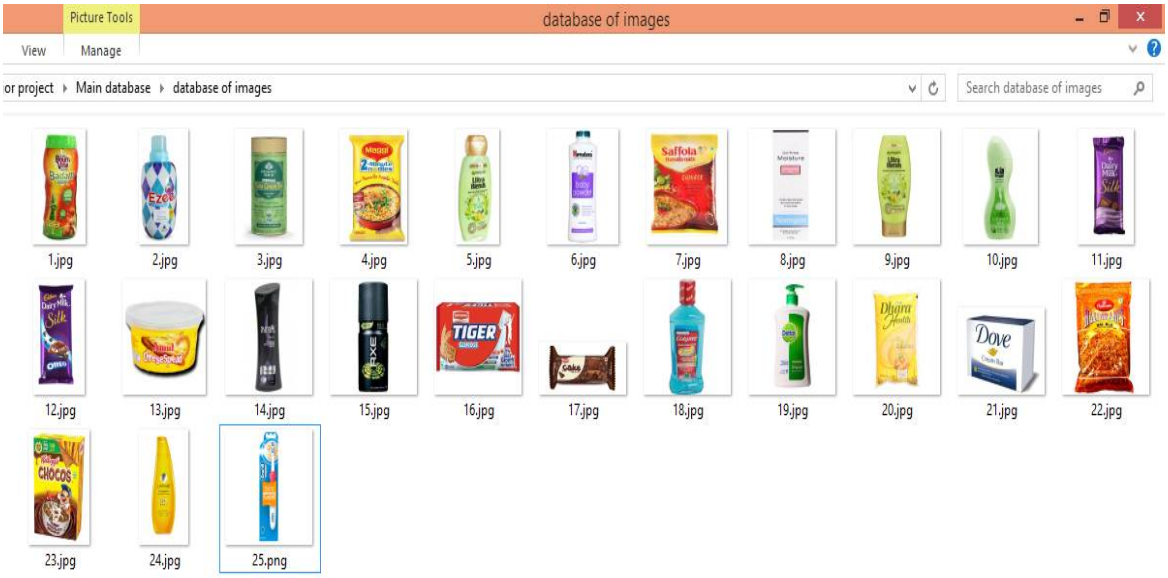

Fig. 2 Database of objects in supermarket

2. Training stage In the training stage, the SIFT, PCA-SIFT and Hybrid PCA-SIFT-FREAK algorithm are trained for the static images of the created database. There are 2 codes for each algorithm- one for database creation and other for matching. The training stage is performed using database creation code. The feature descriptors are generated for each image for which features have been extracted. These are in form of CSV files and saved folder wise from 1 to 25 for each object and for each sample image of the object.

3. Testing stage: Testing is performed using matching code on static test images saved in a folder. Feature descriptors [26] are generated for each test image and matching is done with the CSV file database already generated in training stage using Euclidean distance. The test images are tested using the matching codes of all 3 algorithms. The SIFT, PCA-SIFT and Hybrid PCA-SIFT-FREAK algorithm is tested for static test images saved in a folder. The features of test images are extracted and matching is done with the already trained images. In the MATLAB command window, the object with which the test image matches and the execution time with respect to each test image is displayed. When a match is found, object matched is displayed along with the object's picture else 'no match found' is displayed. Fig. 3 shows key point detection for some objects and matching.

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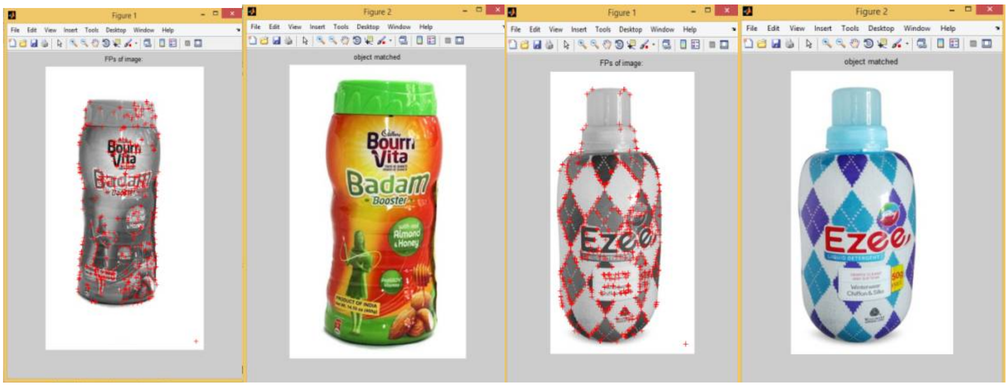

Fig. 3 Key points detection for some objects

IV.COMPARATIVE RESULTS OF SIFT, PCA-SIFT AND HYBRID PCA-SIFT-FREAK ALGORITHMS

The comparative results of SIFT, PCA-SIFT and Hybrid PCA-SIFT –FREAK algorithms are presented inTable 1. The for recognition rate, computation time, memory requirement and confusion matrix are presented.

Table 1: Comparative Results of SIFT, PCA-SIFT and Hybrid Algorithms

	SIFT	PCA-SIFT	Hybrid
Recognition Rate	88%	96%	100%
Size in MB	80.1	61.2	72.2
Time (s)	824	278	300

4.1 Recognition rate: It defines the accuracy of the system. It is equal to No. of correct matches x 100 / (No. of correct matches + No. of incorrect matches). Recognition rate using SIFT, PCA-SIFT and Hybrid algorithm are as shown in Table 1. The accuracy in Hybrid is much better as compared to that of the other algorithms. This is because the best features from both the algorithms i.e. PCA-SIFT and FREAK are taken for matching such that if some of the key points are left out in one algorithm, it is taken care of through another algorithm.This reduces the chance of misidentification and thus improves the recognition rate.

4.2 Size of database: The size of the database in MB (CSV files containing the descriptors) SIFT, PCA-SIFT and Hybrid algorithm as shown in Table 1.This is because each feature descriptor of SIFT is of 128 bytes while each feature descriptor of PCA-SIFT is 20 bytes. Although FREAK being a binary descriptor has very small size of 512 bits, but the Hybrid algorithm uses a combination of PCA-SIFT (20 bytes) and FREAK (512 bits) and therefore, the database size is greater than PCA-SIFT but significantly less than SIFT. The computation time is shown in Table 1. It is maximum for SIFT. The computation time for Hybrid algorithm is slightly more than PCA-SIFT because both PCA-SIFT and FREAK features have to be calculated requiring time.

4.3 Confusion matrix: A confusion matrix presents a summary of results of a classification problem by showing the number of correct and incorrect matches in matrix form. Fig. 4 shows that when SIFT algorithm is used, no match has been found for object 5 and 6but as it cannot be left blank , objects 5 and 6 are shown to match with object 25 which is wrong. Also, object 22 matches with object 21 which is wrong. Thus, there are 22 correct matches and 3 incorrect matches.

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Vol. 6, Issue 7, July 2017

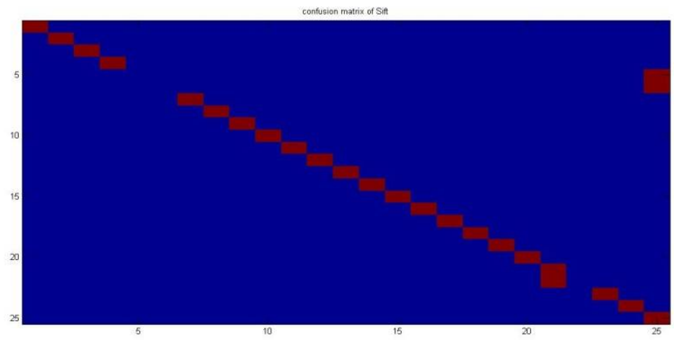

Fig.4 Confusion Matrix for SIFT

Fig. 5shows that when PCA-SIFT algorithm is used, object 25 matches with object 24 which is wrong. Thus, there are 24 correct matches and 1 incorrect match.

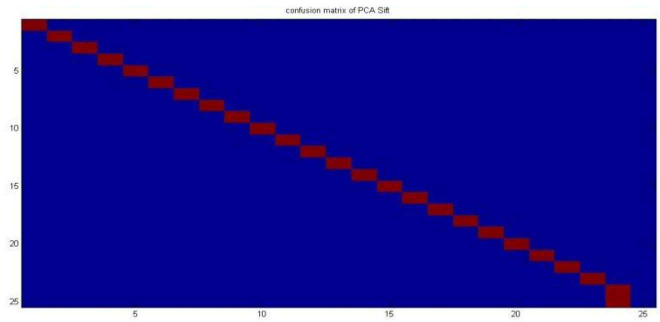

Fig. 5: Confusion Matrix for PCA-SIFT

Fig. 6 shows that when Hybrid algorithm is used, all the objects match correctly. This is because the best features from both the algorithms i.e. PCA-SIFT and FREAK are taken such that if some of the key points are left out in one algorithm, it is taken care of through another algorithm. This reduces the chance of misidentification.

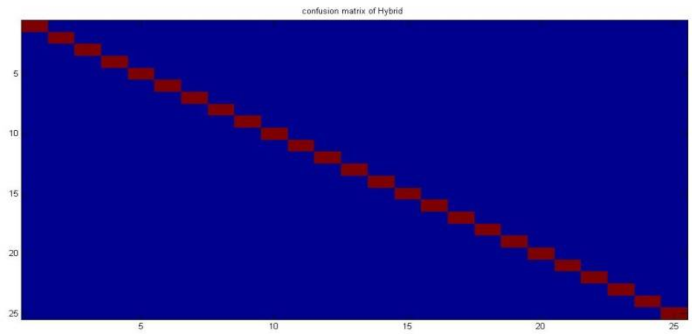

Fig. 6Confusion Matrix for Hybrid Algorithm

V. REAL TIME IMPLEMENTATION

For the real-time object recognition, the setup is done as shown in Fig. 7with camera, laptop and proper background. The camera is placed on the top facing the floor and the objects are placed on the floor making the background as noise

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Vol. 6, Issue 7, July 2017

free as possible to get the maximum accurate results as possible. The GUI is created in the MATLAB for the complete real-time scenario.

Fig. 7Setup of real time system

5.1 Graphical User Interface

The GUI is the window through which the person interacts with the system. It is used for making the system configuration setting, training and testing. Fig. 8 shows the GUI for configuration setting of the background. As the setting in which the system has to be implemented varies, the lighting and background noise varies. The system is configured with this GUI by using the Noise remove and Threshold sliders. Fig. 9 shows the GUI for training stage. New products are learned with the help of image taken by camera and name and price of object is entered. Fig. 10 shows the GUI for testing stage and billing. It helps in real time interface of customer through which he can generate bill. Single or multiple objects are placed in camera frame and display bill is clicked. The names of detected objects along with price and total bill are displayed.

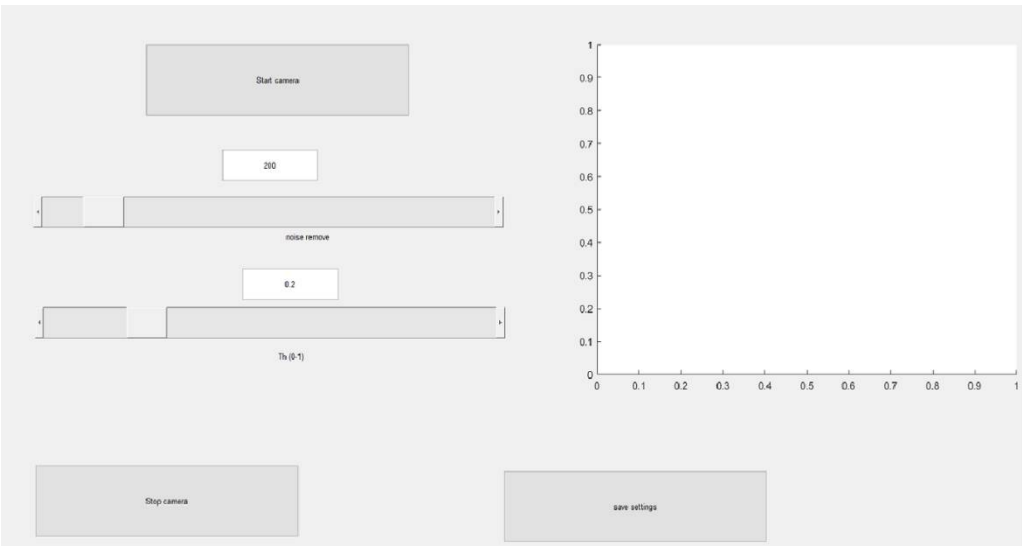

Fig. 8GUI for configuration setting

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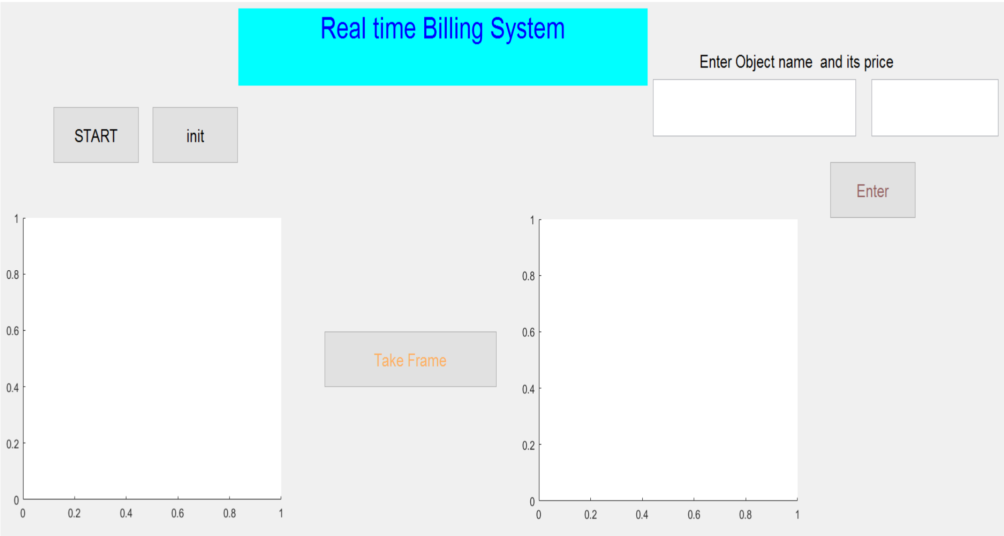

Fig. 9 GUI for training stage

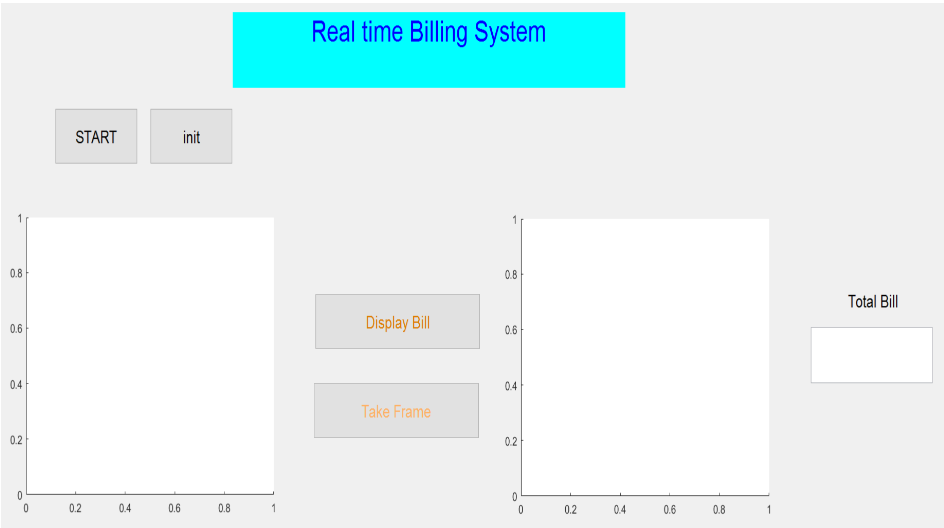

Fig. 10GUI fortesting stage and billing

5.2 Real time object recognition implementation

Fig. 11 shows the configuration setting in real time.First, the configuration setting GUI is run. All the objects from the background are removed. The ‘Start camera’ is clicked. A single click is done on the screen and enter is pressed. Then a black and white image will be visible on the screen. If the whiteness is coming much, then the two slidersfor ‘noise remove’ and ‘threshold’ are increased or decreased. The sliders are moved only till that point where a complete black image is achieved. Then just one object is placed in front of the camera. If it is coming white with black background, then all is correct. Else the sliders are adjusted such that a white image of the object is achieved with a complete black background. When this is achieved, ‘Save Settings’ button is pressed and the configured settings are saved for training and testing.

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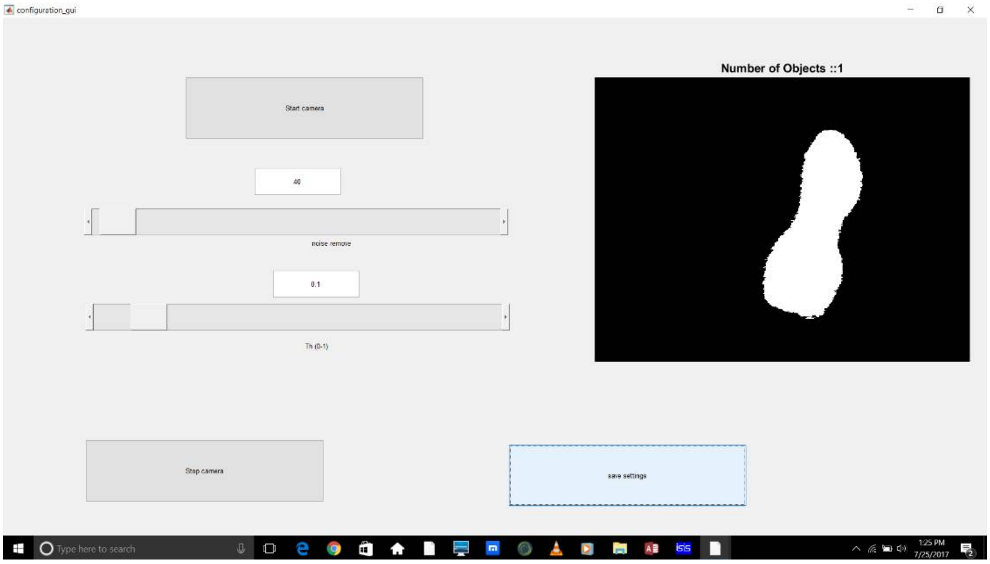

Fig. 11Real time configuration setting

Fig. 12 shows the training of objects in real time.The training GUI is run for training of different objects. First, the ‘START’ and ‘init’ buttons are pressed to start and initiate the camera. Then the name of object to be trained and its price are written in the text box provided in the GUI. ‘Enter’ pushbutton is pressed to save the details. The object is placed in front of camera. Then the ‘Take Frame’ button is pressed by keeping on one object at a time. The feature extraction will be done and features will be saved for the object. It will keep on running in real time. The name and price are kept on changing and frames are taken one by one until all the objects are learned.

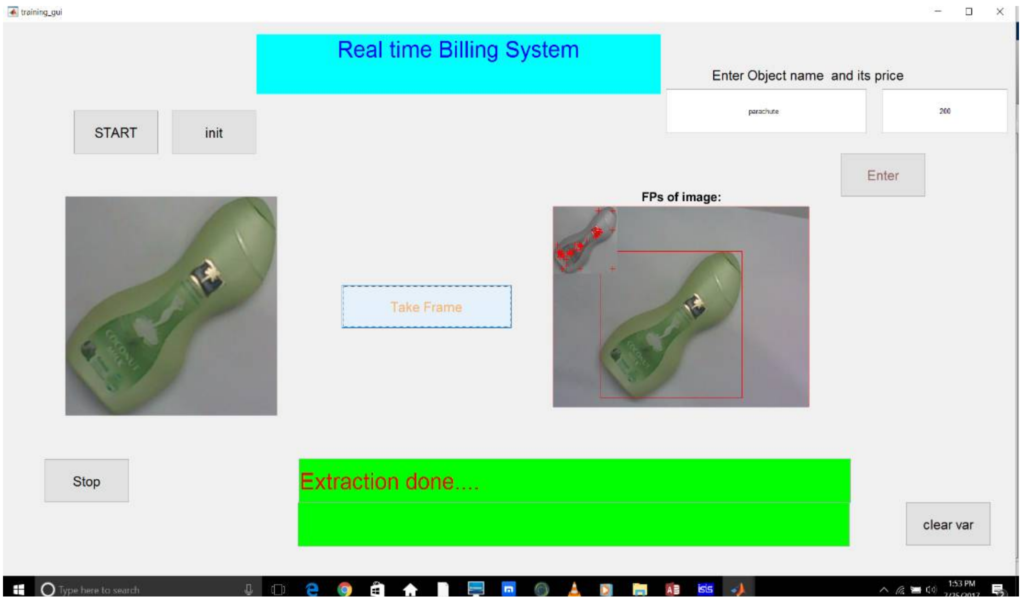

Fig. 12Real time training of object

Fig. 13, 14 and 15 shows multiple object detection and billing for two and three objects.

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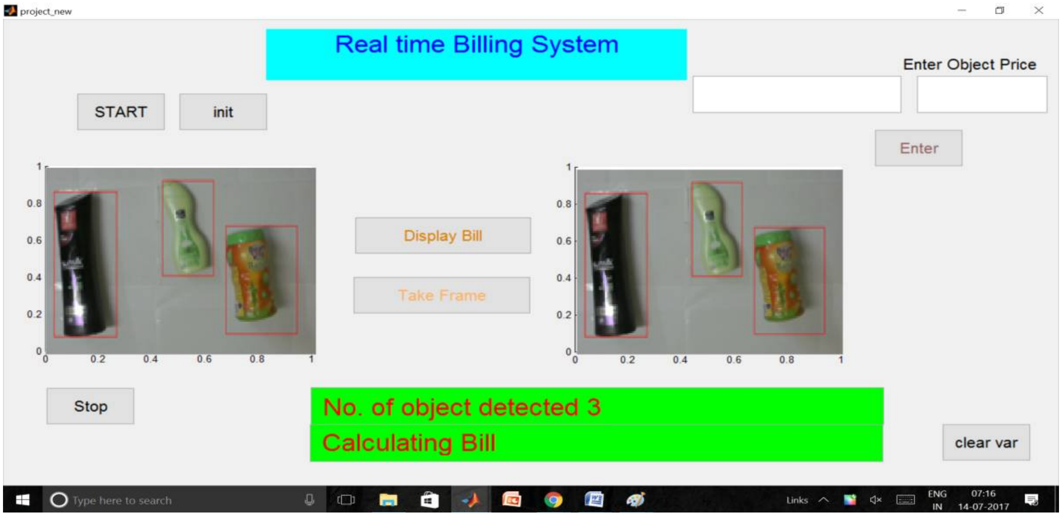

Fig. 13Real time object detection on GUI for 3 objects

This is done using the testing GUI. First ‘START’ and ‘init’ button are pressed to start and initiate camera. Single or multiple objects are placed in the frame of camera and then ‘Display bill’ button is pressed. The system starts detecting the objects in frame. The objects detected in frame are encircled in square box. The key points of detected object's image are extracted and key point matching is done.The name of the object which is recognized along with the price of individual products and total price are displayed.

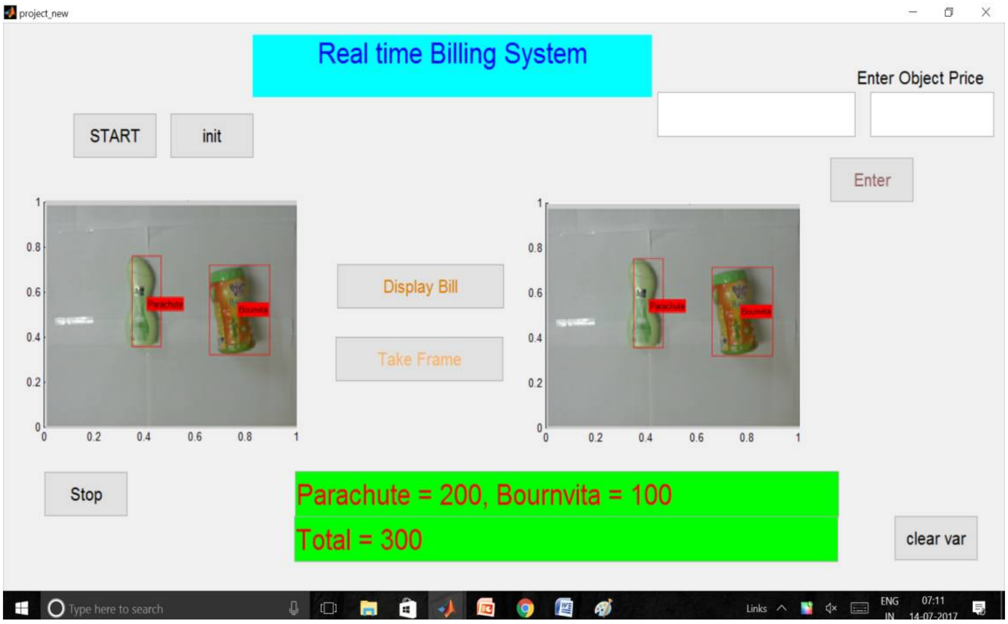

Fig. 14 Real time object detection and billing on GUI for 2 objects

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

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Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

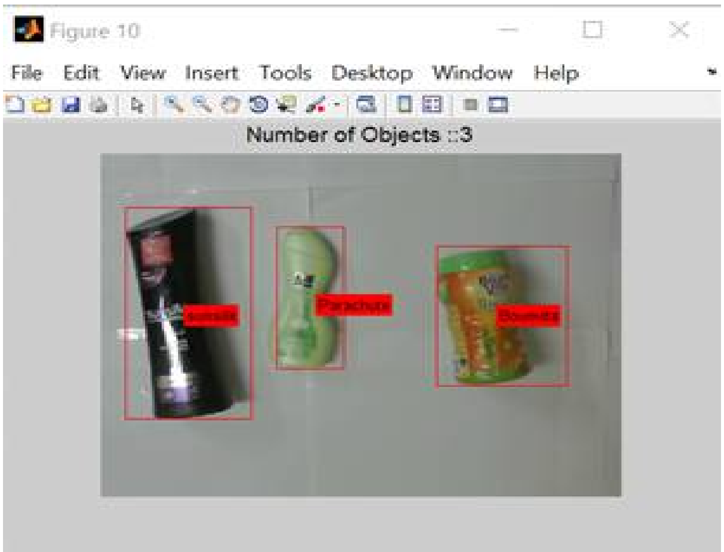

Fig. 15 Real time object detection with names of objects

The automated billing system was thus developed and real time implementation was done for multiple objects. The recognition rate using the proposed Hybrid PCA-SIFT-FREAK algorithm comes out to be 100% the customized database which is better than accuracy from SIFT and PCA-SIFT for the same database.

IV.CONCLUSIONS

SIFT, PCA-SIFT and the Hybrid PCA-SIFT-FREAK algorithms are implemented on the dataset of 25 objects. From the results presented, following conclusions have been drawn.

1. Recognition rate is 88% using SIFT, 96% using PCA-SIFT and 100% by Hybrid algorithm. Thus, the accuracy in Hybrid is much better as compared to that of the other algorithms. This is because the best features from both the algorithms i.e. PCA-SIFT and FREAK are taken for matching such that if some of the key points are left out in one algorithm, it is taken care of through another algorithm.
2. The size of the database in MB is 80.1MB using SIFT, 61.2MB using PCA-SIFT and 72.2MB using Hybrid algorithm. This is because SIFT is a 128 dimension descriptor and occupies maximum memory. PCA-SIFT is a 20 dimension descriptor and takes lesser memory than SIFT. In the hybrid algorithm, descriptor for PCA-SIFT as well as FREAK which is binary descriptor is calculated. Hence it takes slightly more memory than PCA-SIFT but less memory than SIFT.
3. The computation time for 25 objects is 824s, 278s, 300s using SIFT, PCA-SIFT and Hybrid algorithm respectively. It has reduced significantly for PCA-SIFT and Hybrid Algorithm as compared to SIFT. It is slightly higher for Hybrid as compared to PCA-SIFT because both PCA-SIFT and FREAK descriptors are to be calculated for the hybrid. However, the computation time depends largely on the processing speed of the computer and it can be further reduced using commercial purpose computers with good processing capability.
4. The improved recognition rate is a good balance for an application like billing system where accuracy of recognition is very crucial for correct billing. The real time automated billing system is advantageous over a barcode based billing system as multiple objects can be detected simultaneously rather than laser scanning of individual objects. It also reduces human intervention. With further improvements in the system and additional features, object recognition based billing systems can make barcodes obsolete thereby saving cost, time and human capital which is a precious resource.

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ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 7, July 2017

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