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Performance Evaluation of SIFT & FLANN and HAAR Cascade Image Processing Algorithms for Object Identification in Robotic Applications

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Abstract**—** In this paper we present two different algorithms for applications based on image processing for a robotic arm. For feature extraction Scale Invariant Feature Transform (SIFT) algorithm is applied and for local feature matching, the Fast Library for Approximate Nearest Neighbors (FLANN) is applied to match the query image and reference image in data set. This paper also presents a method of image analysis by means of the wavelets–HAAR spectrum. It discusses about the algorithm in which the input frame is compared with data base. It converts BGR values to HSV after which it identifies the contour of object using several iteration process. The performances of both the algorithms are compared based on the time consumption and accuracy. The SIFT algorithm, which provides feature extraction and Flann, which provides feature matching with reference to the training image, when combined would identify the desired object from the input image. The HAAR classifier is based on a database with many images which consists of positive and negative samples. The algorithm runs on image iteration with the database and identifies the desired object from the input image. Size of the database is proportional to the accuracy of the function implemented through HAAR classifier algorithm.

Keywords**— SIFT, Flann, HAAR classifier, positive and negative samples**

I. INTRODUCTION

In the area of industrial robotics, the relation between man and machine only consists of maintaining the machine by the human operator and programming. Image processing has emerged as a vital component in present-day science and technology. The vision sensing is the technology of an intelligent robot. It is largely used in robotics, medical imaging, computer vision, microscopy and various other areas. The main difficulty in recognition system design is the large data base size, only chance to minimize the database is to select the best features. Some algorithms like kd-tree algorithm, the vocabulary tree and the hierarchical k-means tree are not readily suitable for matching binary features because they assume the features exist in a vector space where each dimension of the features is continuously averaged. Flann algorithm helps us with this issue. FLANN is a library for performing fast approximate nearest neighbor searches in high dimensional spaces. Flann can be written in C , Matlab and Python. Corner detection has played an important role in image matching outline capturing system, image representation and other fields. The SIFT and FAST corner detection are the developed method for image matching. There are various applications of SIFT algorithm, one of them being Facial recognition, which is discussed in [14] based on a variety approach. Another type of transform which is used to perform lossy compression so that the compressed image retains its quality is called HAAR wavelet transform. The HAAR wavelet transform is based on image database with varying intensity, background. HAAR wavelet transform is a type of nonlinear discrete wavelet transform [17]. There are extensions possible for HAAR wavelet transform for selective functions such as image and video compressions and human perception on the distorted image and video frames after compression based on HAAR-PSI, which is discussed in [16] for image quality assessment. Eye detection is done using discriminatory HAAR features using 2D HAAR wavelet transform in [20]. A method based on weighted rectangles is implemented in [22] using a modified HAAR-like feature extraction which is comparatively better than the traditional method.

II. PROBLEM STATEMENT

High dimensional spaces consume more time in processing based on nearest neighbor approximations. There are no known exact methodology for solving these kind of high-dimensional problems which are faster than linear search. The most popularly used algorithm for nearest neighbor search is the kd-tree. The kd-tree algorithm works well in case of low dimensionality, but is not effective when the dimensionality is high. The images are represented in pixels in a normal BGR image which are insignificant to the naked eye. Therefore we go for conversion to HSV. HSV color space is the most suitable color space for color based image segmentation. HSV color space consists of 3 matrices, 'hue', 'saturation' and 'value'. Edge detection refers to the technique to recognize and locate sharp discontinuities in an image. Therefore, edge detection is an important step in image analysis and it is the key of solving many complex problems. The main applications of edge detection techniques are in the methods of image segmentation and object detection. Many edge detection algorithms have been developed in the past, but no single algorithm is suitable for all kinds of applications. In this paper the systems implemented would identify the contour of object using several iteration processes based on SIFT & Flann and HAAR Cascade algorithms. When high dimensional video systems are used, as in [12], the SIFT feature matching can be used for video registration, which is an example for high dimensional spaces with dynamic frames. This paper evaluates the performance of the two algorithms used for object detection. The size of the database is different for the systems. HAAR cascade algorithm could be a good replacement for Flann technique when high dimensional spaces are used, which would be validated based on the performance evaluation of both the techniques.

III. RELATED WORKS

SIFT and FAST algorithms are assessed in [1] where the author distinguishes the techniques and suggests the best method. In this paper[2] it discusses about the nearest neighbor search algorithm with the aid of the Voronoi diagram generated from point sets whose drawback lies right in the heavy computing task during the construction of the Voronoi diagram; Corner detection has played an important role in image matching , outline capturing system , image representation and other fields. A variety of quantitatively evaluation methods of corner detection algorithm have been proposed [3, 4]. The kd-tree algorithm [5] most popularly used for nearest neighbor search. Increase in dimensionality reduces the effectiveness of the system unlike when the dimensionality is low. In this paper [6], two widely used corner detection algorithms, SUSAN and Harris corner detection algorithms which are both based on intensity, were compared in stability, noise immunity and complexity quantificational via stability factor η, anti-noise factor ρ and the runtime of each algorithm. In this paper [7], color image compression analysis and synthesis based on HAAR and modified HAAR is presented and it can be used in various areas of image processing such as edge detection, preserving, smoothing or filtering. SIFT algorithm is also implemented through FPGA based on feature extraction and the work is produced in [10].

The SIFT algorithm is also used for optical methods at micro level as in [13] where the algorithm is implemented on mosaics. License plate recognition has been a common procedure in the field of Image Processing, yet it has some limitations, discussed in [15], for which SIFT algorithm is used to overcome. HAAR-like features are used for ECG applications, which are implemented as descriptors in [18]. In paper [19], vehicle recognition is implemented using HAAR-like feature descriptors along with artificial neuron networks, to ensure rapidity in the calculation of feature extracts. Cryptographic applications are discussed in [21] which are lossless key encryption and decryption, HAAR wavelet transform is used in the process to convert the data into frequency domain. Digital watermarking was discussed extensively in [23, 24] which includes applications of HAAR transform in ciphering and also encryption. Likelihood estimation based on MIL framework is done by selecting few discriminative features from the set of available features of HAAR algorithm and is used for object tracking as in [25], in the paper, few high discriminative classifiers are merged as a strong classifier which is used for object tracking. HAAR transform is used in texture segmentation of 1D fractal dimensions from a 2D texture data in [26] and is compared with current existing highly complex algorithm for fractal feature extraction. Flann is based on approximate nearest neighbor algorithm. Joint probabilistic densities are used for facial recognition using the approximate nearest neighbor algorithm with moderate database size in [27]. Cluster detection is another application of nearest neighbor algorithm, as discussed in [28], where in the technique is dynamic and is also capable of eliminating background noise for effective detection. It also detects the clusters of different densities.Feature detection and feature matching serve the video processing purpose by an algorithm which can switch hd videos as in paper [29]. In paper [30], SIFT Algorithm is used in monitoring the flood using computer vision. A portable approach of matching images, template matching is used in [31]. Digital Watermarking is achieved on a similar method in [32]

IV. SYSTEM ARCHITECTURE

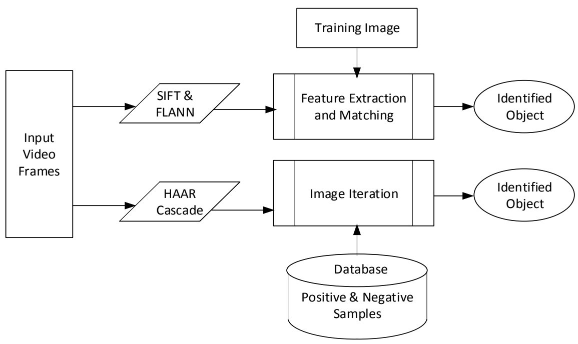

Fig1 : Overall System Architecture

Figure 1 explains the overall system architecture and it represents two systems in parallel. One is based on SIFT & Flann techniques, the other is based on HAAR cascade classifiers. Each of the techniques is unique in its own manner. While the former takes lesser time, the latter is comparatively more accurate. Either case, output would be the same - object identification. The input image from the camera is identified on the basis of two parameters that is colour and shape. The database consists of threshold values for colour and shape detection obtained from the analysis of the collected images. The first step in the two-stage process is the detection threshold i.e., HSV values of the image. The HSV obtained by performing the training algorithm on the previously collected images in the database. This training can be done using SIFT feature extractor. For the precise identification of the object, the colour detection is not the optimal method. Therefore, shape detection of the stem is introduced in the second stage. Shape detection is done via contour identification method. In this stage, the contour of the threshold image will be obtained by running the contour detection algorithm on the input image. The contour must be a quadrilateral if it has four vertices hence it should be the desired object. By identifying the coconut stem from another part of the coconut, the coconut climbing robot can easily cut the coconut bunch in the stem. This makes the system completely automated and accurate. When the coconut height is more than 10 meter, the visibility of the coconut stem by the person in the ground station is very poor. Therefore, the colour and contour based identification of stem decision making are superior and accurate than the manual instruction to the robot. A similar approach is carried out in [9] where in the author used SIFT algorithm to detect the currency, the database is a set of images of the currency which includes coins and notes.

Object detection is a difficult task in the image processing and computer vision. Different parameters are used for the detection of objects. In this paper, we are using colour and shape as the two parameters to identify the object from the image. The object which we want to identify is an arduino board and a notebook and have to remove all other parts. Two parameters are used for object detection is colour and shape. The HSV values of the objects are identified by evaluation of directly set values using track bar. These HSV values are the threshold for the selection. Noise in the threshold image is removed by morphological opening and closing. The morphological opening is done for removing small objects from the foreground and morphological closing fill small holes in the foreground. This procedure makes the threshold image noise free. In order to confirm the object, second parameter shape identification is introduced and contours of the threshold image is detected. Performing the quadrilateral check in each contour of the threshold image by iterations. If there we can find four vertices contour in the threshold image, it should be quadrilateral and that is the identified object and the required portion. The proposed method is very simple accurate one for the robotic arm in order to make it real time and automated. There are few limitations of SIFT algorithm for feature extraction, which are related to feature descriptors and a new method is proposed based on statistical distributions in [11].

Identifying objects and shapes has been possible by OpenCV with the help of additional algorithms and programming. The identification is possible through various methods. Another method which uses database matching is HAAR Cascade Transform. Cascade classifier for HAAR features enables us to identify objects of different shapes and colours. The system should be trained with sample images which are a set of images of the object. The cascade classifier communicates with the OpenCV libraries to give the system the search parameters in an image for it to be identified. Usually cascade classifiers are those which store the information of the object to be identified. The classifier can be customized based on our requirement to detect desired object. It needs to be trained with a lot of positive sample images, which we call as database for proper detection. It also requires negative sample images which are the images without the object to be detected for it to discriminate between the images and identify the object. The number of images required as database depends on various factors such as quality of image, structural complexity of the object. In order to obtain an accurate classifier, a huge database is required and it consumes a lot of time. The positive images selected as database should also differ in parameters such as luminance and background. The images in the database should be of similar sizes with not much variation in dimensions. The negative images could be anything without the desired object for detection in them. Some of them could be of the same background as positive images. Communication between the HAAR classifier and OpenCV enables us to train the classifier with the database. The OpenCV also prints out some analyses while the classifier is being trained with the database of the images provided. The database can range from few hundreds to thousands of images, depending on the size of the database, the training time varies. It also consumes a good amount of memory in the CPU. Once the classifier is trained, it can be used to detect the images using OpenCV and python or any programming language. The algorithm tries to match the camera feed with the database already embedded in it and thus enables the user to detect the desired object.

V. IMPLEMENTATION

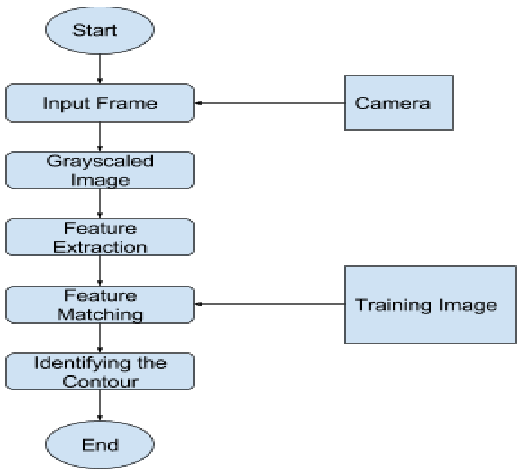

Fig 2: Algorithm for object detection using SIFT and Flann.

Nowadays different methods are used for the object recognition such as appearance-based methods, feature extraction methods, and CAD object models methods. In this paper we are using the appearance-based methodology, such as the input is given by the camera. The algorithm used for this system is applicable in a nondeterministic plane. The prior data required is only for the HSV values algorithm and for the shape of the object. Data can be obtained from the database of collected image i.e the training method. One of the methods this can be done is using SIFT and Flann based matcher. In SIFT and Flann based matcher, we will be using a training image which is the image that is to be tracked. The training image is saved and is used to track the object in the live camera feed. SIFT feature extractor will extract some distinct features from the images as key points for our object recognition and we will also need a feature matcher which will match the features from the sample/ training image with the current image from the camera. Here, the feature extractor SIFT acts as detector and feature matcher is Flann. Figure 2 explains the algorithm used in detecting the target object. Initially, the frame is captured from the camera, then converted into a grayscale image, then features are extracted using the training image. Flann feature matcher is used to match the features in both images and detect the required target object.

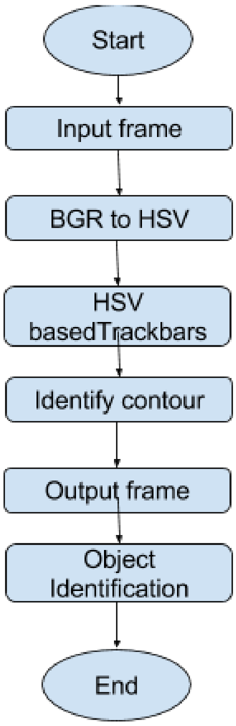

Fig 3. Algorithm for object detection based on HSV

It is also possible to provide the threshold values directly so that no database is required. Figure 3 explains the algorithm for object detection based on HSV. Here, once the system gets trained for the algorithm there will be no need to train for the whole object having a unique color. It also explains how the HSV values help in identifying the required object to be detected. Here, the camera images are the source of information, it extracts the data from the image using the image processing techniques. Linux and open source computer vision libraries are used for the image processing. OpenCV receives images in BGR format. It includes matrices of blue, green and red the values in the matrices ranging from 0 to 255. Conversion of the BGR image into HSV format is appropriate for this system as HSV color space is most suitable for the color-based classification. BGR is same as that of the RGB format but in BGR red occupies the least significant area. OpenCV supports BGR format. HSV values can be adjusted using the track bars. The significant part in the artificial intelligence of an automated system is the vision i.e. it identifies the object with the help of the camera.

HSV is the cylindrical coordinate representation of color. By setting the specific range of values in HSV scaling, the required object can be identified. The degree of specificity of HSV values determines the accuracy of the algorithm i.e. they are linearly dependent. The specific values can be obtained from the database or analysis of the collected images. For the object, in most of the cases, color is yellowish green. So, HSV values are to be set for yellowish green color. To get the accurate and precise HSV values, the optimal number of the images analyzed by the algorithm should be 10.

Coherent and non-coherent noise is present in the threshold image. The noise removal is done by morphological opening and closing. The threshold image is a binary image (after the color detection). Morphological operations are done on binary images. Dilation, erosion, opening, closing, hit and miss transform, thinning, thickening, skeletonization/medial axis transform are different methods in the morphological operations. In this paper, we are using dilation and erosion for noise removal. By Dilation grew the image region and erosion is used to shrink the image region. The morphological opening is used to remove small objects from the foreground and morphological closing is to fill small holes in the foreground. Here morphological opening includes gray level erosion followed by gray level dilation. Morphological closing is just a reversal of the opening, in that dilation followed by the erosion is takes place. All these operations are taking place in the binary image (grayscale image). A grayscale image is a single channel image so the processing is simple and accurate. In multichannel images, edge detection and noise removal are comparatively difficult and not that much accurate.

Recognition using color is a powerful and simple method, in this match the color of the image or color-related parameters for the object detection. But it has a drawback that when the illumination changes, it affects the accuracy. This drawback can be avoided by the shape detection. In this paper, training methods for contour detection are used. So by this color and shape detection, the object is identified.

For practically detecting the object in real time, a more sophisticated method is required. One such method would be the detection of objects from images using features or specific structures from a collection of images. In this paper, the second method used for object identification is HAAR classifier. Here, a HAAR-cascade classifier for detecting an "Arduino Uno board" is developed. HAAR-cascade is an object detection algorithm which used for object identification and face detection methods. In the HAAR-cascade classifier, a large number of positive images are provided to the system where the positive images contain the database of the object images taken in various orientations and lighting conditions. Similarly, the database of the negative images contain the images of the object other than the object that is to be detected. The feature selection for object identification is done with the classifier training using the AdaBoost and the integral images.

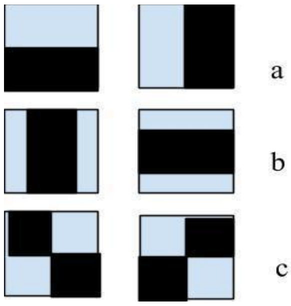

Fig. 4. Types of rectangular features

There are three kinds of rectangular features used and are shown in figure 4. In the first one (a), the sum or difference of the pixels within the two rectangular regions is taken. These rectangular regions have the same size and shape and are vertically or horizontally adjacent. In the second one (b), the sum of the two outer rectangles is taken and then it is subtracted with the sum of the center rectangle and there by computing the three rectangular features. In the third one (c), the difference between the diagonal pairs of the rectangles is taken and there by computing the four rectangle features. The classification process requires a large set of the negative images and the positive images which are useful for training process. The Ada-boost algorithm is used to increase the performance.

In order to create HAAR cascade positive images, we have used 40 positive images of Arduino Uno board. These images are taken at different illuminations, different angles, and different orientations. Similarly, 600 negative images are taken. Here, the negative images can contain any object other than the object that is to be detected. The more varying the images are, the better will be the performance of the algorithm. The negative and positive images are used to create the training samples. Two types of samples - positive and negative, are needed for the training process. 600 negative images are taken as negative samples. Here, Combining of each positive image with a random negative image is done and then it is run through the OpenCV. Since it allows the training process to be multi-threaded, the time it takes to finish the required detection of the required object is not so high compared to SIFT and FLANN.

VI. EXPERIMENTS AND RESULTS

As the process of segmentation of the required part of image which contains the desired object should be least dependent on various factors like shadows, lighting conditions, etc., the acquired image is processed in HSV rather than in BGR format. A collection of pre-acquired images are studied to get a range of HSV values for thresholding and is made into a database. Image acquisition is done using an onboard camera attached near the end effector of the arm. Color training is done using various HSV parameters using a pool of assorted polka dots on a white background. A track bar is used to vary the HSV parameters to get the optimum dot detection with the least noise and error. The experiments were done in lighting conditions that are comparable to natural lighting conditions.

Once the image is set to threshold on basis of color, it is further processed with morphological operations. Morphological opening and closing are two operations that are done on the threshold image to acquire the desired part of the bunch. Morphological opening and closing are given by the Equation (1) and Equation (2) respectively.

$$IT(x,y) \circ Se(x,y) = \{[IT(x,y) \ominus Se(x,y)] \oplus Se(x,y)\} \quad (1)$$

$$IT(x,y) \bullet Se(x,y) = \{[IT(x,y) \oplus Se(x,y)] \ominus Se(x,y)\} \quad (2)$$

where the IT(x,y) is the threshold image and Se(x,y) is the structuring element; $\oplus$ denotes morphological dilation operation and $\ominus$ denotes morphological erosion operation.

Experimentation with various training techniques is done. The first technique used is SIFT feature extractor and Flann based matcher. Here, Figure 5 shows the training image of object 1 that is used to detect the required object from the live video feed. Here, a notebook is used as a training image. Figure 6, Figure 7 shows the required object that is detected in different orientations.

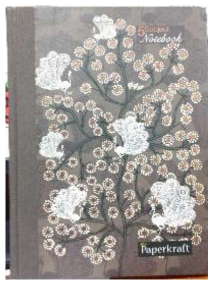

Fig 5. Training image used in SIFT and Flann

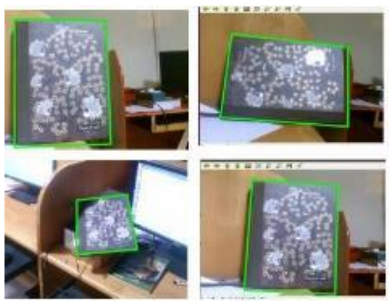

Fig 6. Object 1 detected using training method

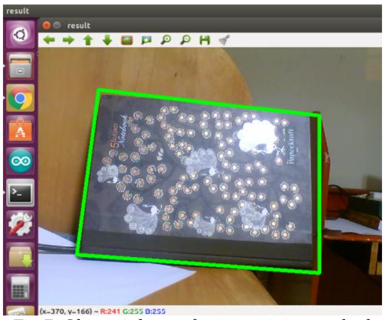

Fig 7. Object 1 detected using training method

Similarly, figure 8 shows the training image of object 2 that is used to detect the required object from the live video feed.

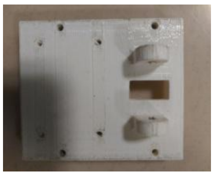

Fig 8. Training image of object 2

Here, a 3D printed object is used as a training image. Figure 9 shows the required object that is detected indifferent orientations.

Fig 8. Object 2 Detected using Training method

In the HAAR classifier method, 40 positive samples and 600 negative samples are used for the object detection. Here, the target object is an arduino. This method has been successful in detecting object rotated at various angle and captured at various angle of perception as shown in figure 9. HAAR classifier has performed exceptionally well for detecting an object in a frame even when the background had lot of details. This method is favorable to detect objects that are universally identical i.e., two target objects look similar and have common features.

Fig 9: Results at various orientation levels using HAAR Cascade

VII. CONCLUSION

In this paper, two methods for object detection and tracking of an object in real time is discussed which is done using a camera that can detect the object based on SIFT & FLANN and HAAR cascade classifier. This system can be used to track the object accurately. In the first approach we used the SIFT algorithm, which provides feature extraction and Flann algorithm, which provides feature matching with reference to the training image, to identify the desired object from the input image. In the second approach, the HAAR algorithm based on a database with many images which consists of positive and negative samples is used for object identification in a given image. The algorithm was run on image iteration with the database and used to identify the desired object from the input image. The evaluation and the results shows that HAAR algorithm is better in identifying the object as it is multithreaded process and takes almost same time as SIFT and FLANN but much more accurate in detection the object.

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