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An Overview on Template Matching Methodologies and its Applications

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***Abstract*—A very common task in pattern recognition is template matching. The detection and recognition of objects in images is a key research topic in the computer vision community. Within this area, image recognition and interpretation has attracted increasing attention owing to the possibility of unveiling human perception mechanisms, and for the development of practical biometric systems. Various template matching methodology like NTM, ICM, PCM, GBM, EBM are explored.Template matchingis applied in versatile field such as signal processing, image processing, pattern recognition, and video compression.This paper provides the descriptive overview of applications and methodologies were template matching techniques are explored.**

***Keywords*—Navie Template Matching(NTM), Image Correlation Matching(ICM), Pattern Correlation Image(PCI), Grayscale Based Matching(GBM), Edge Based Matching(EBM), biological science, computer vision, agriculture science, remote sensing**.

I. INTRODUCTION

Template Matching is a high-level machine vision technique that allows to identify the parts of an image (or multipleimages) that match the given image pattern. It can be used in manufacturing as a part of quality control, a way to navigate a mobile robot, or as a way to detect edges in images. In this we see all various methodologies which is used for implementing Template Matching.

Template Matching is a technique for finding areas of an image that match (are similar) to a template image (patch) [1].We need two primary components-

Source image (I): The image in which we expect to find a match to the template image.

Template image (T): The patch image which will be compared to the template image. our goal is to detect best technique for the highest matching area.

Template matching is one of the areas of profound interests in recent times [2]. It has turned out to be a revolution in the field of computer vision. Template matching provides a new dimension into the image- processing capabilities, although there have been many attempts to resolve different issues in this field. Template Matching is a high-level machine vision technique that allows to identify the parts of an image (or multipleimages) that match the given image pattern. Advanced template matching algorithms allow finding the pattern occurrences regardless of their orientation and local brightness.

II. TEMPLATE MATCHING APPROACHES

The choice of matching depends on the nature of the image and the problem to be solved. General classifications of template or image matching approaches are: Template or Area based approaches and Feature-based approaches.

- Featured-based approach**:**

Featured-based approach is well suited when both reference and template images had more correspondence with respect to features and control points. Features include points, curves, or a surface model that have to be matched. Here, the aim is to locate the pair wise connection between reference and template using their spatial relations or descriptors of features. Subcategories of the above approach are spatial relations, invariant descriptors, pyramids and wavelets and relaxation methods.

- Area-based approach**:**

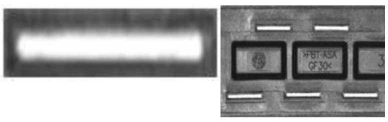
Area-based methods are sometimes called as correlation-like methods or template matching methods. Fonseca andManjunath (1996) [3], which is the combination of feature detection and feature matching Motion tracking and occlusion handling:

For the templates which may not provide a direct match, then Eigen spaces are used, which gives the detail of matching image under various conditions, as illumination, color contrast or acceptable matching poses.

III. METHODOLOGIES.

1. NAVIE TEMPLATE MATCHING:

Imagine that we are going to inspect a picture of a plug and our goal is to find its pins. We are provided with the pattern image representing the reference object we are looking for and the input image to be inspected.



Pattern Image Input Image

Fig1: Represents the pattern image to be matched in input image.

This paper perform the actual search in rather straightforward way – in which, position the pattern over the image at every possible location, and each time we will compute some numeric measure of similarity between the pattern and the image segment it currently overlaps. Finally we will identify the positions that yield the best similarity measures as the probable pattern positions.

2. IMAGE CORRELATION MATCHING:

One of the sub problems that occur in the specification above is calculating the similarity measure of the aligned pattern image and the overlapped segment of the input image, which is equivalent to calculating a similarity measure of two images of equal dimensions. This is a classical task, and a numeric measure of image similarity is usually called image correlation.

A. Cross-Correlation:

TABLE 1
Describes the cross correlation of two images

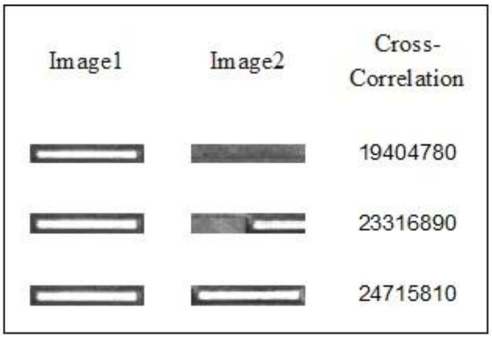


Image1	Image2	Cross-Correlation
		19404780
		23316890
		24715810

The fundamental method of calculating the image correlation is so called cross-correlation, which essentially is a simple sum of pairwise multiplications of corresponding pixel values of the images. The cross-correlation function plays an important role in matching the characteristic features on the cartridge case found at the crime scene with a specific firearm, for accurate firearm identification [4].

It has been an extensively studied topic for the last several decades, and a large number of matching algorithms have been proposed in the literature [5]-[6].

Though we may notice that the correlation value indeed seems to reflect the similarity of the images being compared, cross-correlation method is far from being robust. Its main drawback is that it is biased by changes in global brightness of the images - brightening of an image may sky-rocket its cross-correlation with another image, even if the second image is not at all similar.

Cross-Correlation(Image1, Image2)=

$$\sum_{x,y} Image1(x,y) \times Image2(x,y)$$

B. Normalized Cross-Correlation:

TABLE 2
Describes the Normalized cross correlation of two images

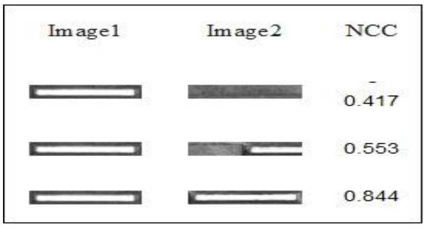


Image1	Image2	NCC
		-0.417
		0.553
		0.844

NCC(Image1, Image2)=

$$\frac{1}{N\sigma1\sigma2\sigma}\sum_{x,y} \begin{matrix}(Image1(x,y) - \overline{Image1}) \times \\ (Image2\ (x,y) - \overline{Image\ 2})\end{matrix}$$

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Normalized cross-correlation is an enhanced version of the classic cross-correlation method that introduces two improvements over the original one:

- The results are invariant to the global brightness changes, i.e. consistent brightening or darkening of either image has no effect on the result (this is accomplished by subtracting the mean image brightness from each pixel value).
- The final correlation value is scaled to [-1, 1] range, so that NCC of two identical images equals 1.0, while NCC of an image and its negation equals -1.0.

Normalized cross-correlation is widely used as an effective similarity measure for matching applications. Normalized cross-correlation is invariant to linear brightness and contrast variations, and its easy hardware implementation makes it useful for real-time applications. However, traditional correlation-based image matching methods will fail when there are large rotations or significant scale changes between the two images. This is because the normalized cross-correlation is sensitive to rotation and scale changes. Therealso exist generalized versions of cross-correlation that calculate the cross-correlation for each assumed geometric transformation of the correlation windows [7]-[8].

3. PATTERN CORRELATION IMAGES:

Let us get back to the problem at hand. Having introduced the Normalized Cross-Correlation - robust measure of image similarity - we are now able to determine how well the pattern fits in each of the possible positions. We may represent the results in form of an image, where brightness of each pixel represents the NCC value of pattern positioned over this pixel (black color representing the minimal correlation of -1.0, white color representing the maximal correlation of 1.0).

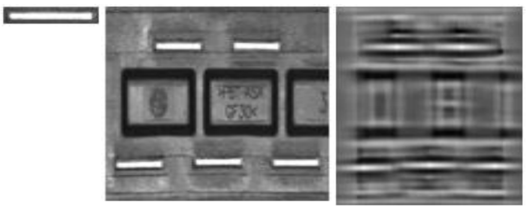

Fig 2: (1) Represent pattern image (2) Input image (3) Pattern Correlation image.

1) Identification of Matches

All that needs to be done at this point is to decide which points of the pattern correlation image are good enough to be considered actual matches. Usually we identify as matches the positions that (simultaneously) represent the pattern correlation:

- stronger that some predefined threshold value (i.e stronger that 0.5)
- locally maximal (stronger that the pattern correlation in the neighboring pixels)

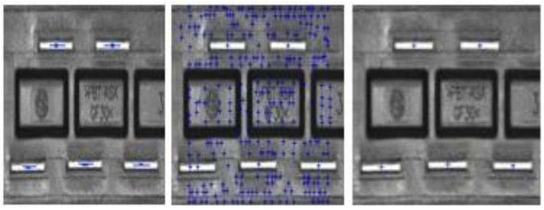

Fig 3: (1) Areas of pattern correlation above 0.75 (2) Points of locally maximal pattern correlation (3) points of locally maximal pattern correlation above 0.75

DRAWBACK OF ABOVE METHODS:

Though the introduced technique was sufficient to solve the problem being considered, we may notice its important drawbacks:

Pattern occurrences have to preserve the orientation of the reference pattern image.

The method is inefficient, as calculating the pattern correlation image for medium to large images is time consuming.

IV. ADVANCE METHODS

1. GRAYSCALE-BASED MATCHING:

Grayscale-based Matching is an advanced Template Matching algorithm that extends the original idea of correlation-based pattern detection enhancing its efficiency and allowing searching for pattern occurrences regardless of its orientation.

Although in some of the applications the orientation of the objects is uniform and fixed (as we have seen in the plug example), it is often the case that the objects that are to be detected appear rotated. In Template Matching algorithms classic pyramid search is adapted to allow multi-angle matching, i.e., identification of the rotated instances of the pattern.. It has many applications ranging from computer animation and virtual reality to human motion analysis and human-computer interaction (HCI) [9]-[10].

This is achieved by computing not just one pattern image pyramid, but a set of pyramids - one

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for each possible rotation of the pattern. During the pyramid search on the input image the algorithm identifies the pairs (pattern position, patternorientation) rather than sole pattern positions. Similarly to the original schema, on each level of the search the algorithm verifies only those (position, orientation) pairs that scored well on the previous level (i.e. seemed to match the pattern in the image of lower resolution).

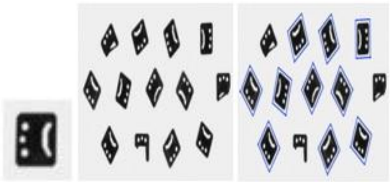

Fig 4: (1)Pattern image (2) Input image(3) Results of multi-angle matching

The technique of pyramid matching, together with multi-angle search constitute the Grayscale-based T-Matching method.

2. EDGE-BASED MATCHING:

Edge-based Matching enhances this method even more by limiting the computation to the object edge-areas Edge-based Matching enhances the previously discussed Gray-scale-based Matching using one crucial observation - that the shape of any object is defined solely by the shape of its edges. Therefore instead of matching of the whole pattern, we could extract its edges and match only the nearby pixels, thus avoiding some unnecessary computations. In common applications the achieved speed-up is usually significant.

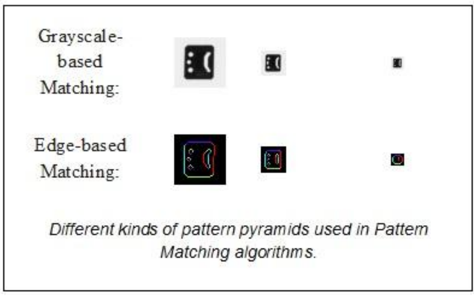

Fig 5: describes the different pattern matching algorithms

Matching object edges instead of an object as a whole requires slight modification of the original pyramid matching method: imagine we are matching an object of uniform color positioned over uniform background. All of object edge pixels would have the same intensity and the original algorithm would match the object anywhere wherever there is large enough blob of the appropriate color, and this is clearly not what we want to achieve. To resolve this problem, in Edge-based Matching it is the gradient direction (represented as a color in HSV space for the illustrative purposes) of the edge pixels, not their intensity, that is matched.

V. APPLICATION AREA:

1. BIOLOGICAL SCIENCE:

Several applications of image processing technology for biology and agriculture have been developed in the collaborative programs involving scientists and engineers from Electronics Systems Division, Computer Division, Molecular Biology & Agriculture Division, Nuclear Agriculture & Biotechnology Division and Cell Biology Division. These applications involve use of the camera based hardware systems or color scanners for inputting the images. The software packages developed for biology include the BIAS software based on DOS and Windows compatible Color-Pro software developed in Electronics Systems Division and Comprehensive Image Processing Software (CIPS) developed in Computer Division. The salient features of these applications are described in the following:

Color image analysis for estimation of leaf area, infected leaf area and chlorophyll Leaf area estimation is very important in plant breeding. Earlier, leaf area meters were employed for this purpose. Now, image analysis can be used to measure the leaf area. Images of the leaves captured by a camera or a scanner are analyzed by the Color Pro software package developed by Electronics Systems Division. A variety of color plates and chlorophyll meters were previously used to monitor chlorophyll content of leaves *in situ*. The Color Pro software can also be used for quantitative estimation of chlorophyll in situ.

The Color Pro software measures the intensity of color for each leaf disk Fig. 6(a) in an arbitrary unit of intensity called inverse integrated gray value per pixel which is proportional to the actual concentration of chlorophyll per pixel Fig. 6(b). Thus the concentration of chlorophyll per pixel can be measured from the color image of any leaf taken under standard conditions of illumination. The concentration of chlorophyll per pixel multiplied by the area of leaf in pixels will yield the total concentration of chlorophyll per leaf.

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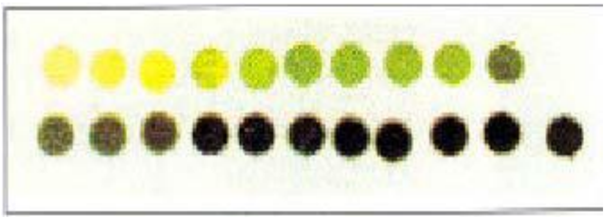

Fig.6 (a)an arbitrary unit of intensity called inverse integrated gray value per pixel which is proportional to the actual concentration of chlorophyll per pixel Fig. 6(b).

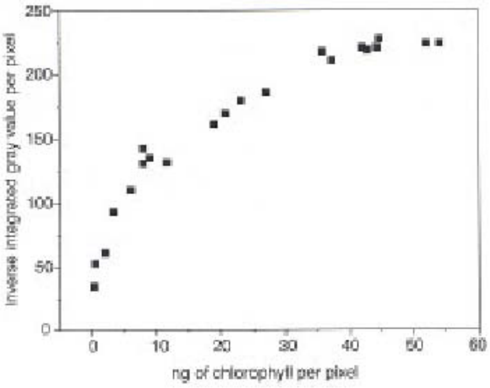

Fig.6 (b)

A. PROTEIN ESTIMATION BY COLOR PRO:

Protein estimation is an important technique in many biochemical experiments including those associated with plant biochemistry. Most routinely used methods of protein estimation are based on spectrophotometric measurements, which are cumbersome, laborious and may require large quantities of protein. A new method has been developed for protein estimation using the Color Pro software (Bannur, et al. 1999).

B. COLONY COUNTING BY IMAGE ANALYSIS:

The advent of biotechnology has resulted in a need for adaptation of microbial techniques in many fields of applied biology. The Color-Pro software has routines, which can be used for counting bacterial colonies. Different parameters of the colony like intensity, size, form factor, connectivity and color in the image can be taken into consideration while counting the colonies.

C. USE OF IMAGE ANALYSIS IN STUDY OF ELECTRO-PHORE GRAPHS:

Electro-phoretic separation of the proteins on polyacrylamide gels is a commonly used technique in biology. The protein gels often show large number of bands, which have to be compared among different samples.

D. SOFTWARE FOR AUTOMATED READING OF DNA SEQUENCING AUTORADIOGRAPHS DNA :

Sequencing, the method of determining the order of occurrence of nucleotides in a DNA molecule is commonly performed either by the chain termination method or by the chemical degradation method. Fig.6 (c) shows an example of a DNA sequencing autoradiograph and the sequence as determined from it**.**

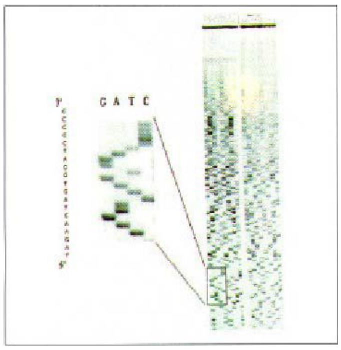

Fig 6(c)

It is a many-to-one mapping. A variety of surfaces with differentmaterial and geometricalproperties, possibly under different lighting conditions, could lead to identical imagesInverse mapping has non unique solution (a lot of information is lost in the transformation from the 3D world to the 2D image)It is computationally intensiveWe do not understand the recognition problem.

2. IMAGE PROCESSING

An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows. In a (8-bit) gray scale image each picture element has an assigned intensity that ranges from 0 to 255. A gray scale image is what people normally call a black and white image, but the name emphasizes that such an image will also include many shades of gray.

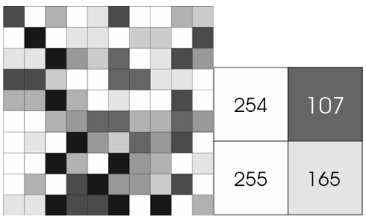

Fig 7:each pixel has a value from 0 (black) to 255 (white). The possible range of the pixel values depend on the color depth of the image, here 8 bit = 256 tones or gray scales. A normal gray scale

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image has 8 bit color depth = 256 gray scales. A "true color" image has 24 bit color depth = 8 x 8 x 8 bits = 256 x 256 x 256 colors = ~16 million colors. A normal gray scale image has 8 bit color depth = 256 gray scales. A "true color" image has 24 bit color depth = 8 x 8 x 8 bits = 256 x 256 x 256 colors = ~16 million colors.

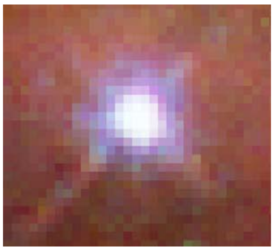

Fig: 8: true- color image assembled from three gray scale images color red, green and blue. Such an image may contain up to 16 million different colors. Some grey scale images have more grey scales, for instance 16 bit = 65536 grey scales. In principle three grey scale images can be combined to form an image with 281,474,976,710,656 grey scales.

3. FACE DETECTING IN IMAGE PROCESSING

Definition of face detection: given an arbitrary image, the global of face detection to determine is to determine whether or not there are any faces in the image and, if present, return the image location and extent of each face.

(a)

(b)

Fig. 9: (a)-(b) face images, to the right zoomed version of eyes extracted from face.

Human facial features play a significant role for face recognition and Neurophysiologic research. According to studies it is determined that eyes, mouth, and nose are amongst the most important features for recognition. Recognizing someone from facial features makes human recognition a more automated process. Basically the extraction of facial feature points, (eyes, nose, and mouth) plays an important role in many applications, such as face recognition, face detection, model based image coding, expression recognition, facial animation and head pose determination. Human faces have a variety of emotions by many different expressions, but this system can detect the corner of the features in the case of neutral, sad, happy and surprise.

Fig10: Describes the facial detection technique using template matching method

Template matching methods are also applied in facial feature extraction methods which are sensitive to various non-idealities such as variations illumination, noise, orientation, time-consuming and color space used[11]. Also a good feature extraction will increase performance of face recognition system.

4. EYE DETECTING IN FACIAL IMAGE:

Eye detection is a pre-requisite stage for many applications such as human–computer interfaces, iris recognition, driver drowsiness detection, security, and biology systems. In this paper, template based eye detection is described. The template is correlated with different regions of the face image. The region of face which gives maximum correlation with template refers to eye region. The method is simple and easy to implement. The effectiveness of the method is demonstrated in both the cases like open eye as well as closed eye through various simulation results.

- *The Algorithm:*

The method of template matching is given as an algorithm, which is simple and easy to implement. The algorithm steps are as follows:

***Step 1*:** An eye template of size $m \times n$ is taken.

Step 2: The normalized 2-D auto-correlation of eye template is found out.

Step 3: the normalized 2-D cross-correlation of eye template with various overlapping regions of the face image is calculated.

Step 4: The mean squared error (MSE) of auto correlation and cross-correlation of different regions are found out. The minimum MSE is found out and stored.

Step 5**:** the region of the face corresponding to minimum MSE represents eye region.

Matching technique not only takes the similarity measure but also calculates the error between images depending on its difference using Mean Squared Error.

- *Image Processing Toolbox :*

Perform image processing, analysis, visualization, and algorithm development,Image analysis Image, enhancement,spatial transformation, Imageregistration, Morphological operation, mage display and exploration. Which can quantify the micro-scopes images of cells and chromosomes with the help of a CCD camera mounted on the camera port of a trinocular microscope. Image processing techniques can be used to effectively measure deformation and cracking characteristics in a variety of materials. Techniques were developed based on MATLAB programming language and utilized many of the available routines in the package in addition to the user developed algorithms. Use of full field applications allows a better understanding of the deformations taking place under load.

5. COMPUTER VISION:

Computer deals with the development of the theoreticaland algorithmic basis by which useful information about the 3D world can be automatically extracted and analyzed from a single ormultiple 2D images of the world. Computer vision is also known as, Image Analysis,Scene Analysis,and Image Understanding in which template matching is highly implemented.

Fig11: Examples of computer vision application.

6. REMOTE SENSING:

Remote sensing can be used scene at specific wavelengths simultaneously, resulting in hundreds of digital images. The data collected from a hyper spectral sensor contains not only the visible spectrum, but also ultraviolet and infrared ranges as well. It is common to list the hyper spectral data in a three-dimensional array or “cube”, with the first two dimensions corresponding to spatial dimensions and the third one corresponding to the spectrum. In hyper spectral classification and especially target detection, the main task is to find the spatial pixels in three dimensional hyper spectral cube data for some given spectral signals of interest. However, this becomes difficult because of the uncertainty and variability of each material’s spectral signature. The difficulties include the noise from atmospheric conditions, sensor influence, location, illumination and so on, all of which depend on when and where the image was taken.

VI. LIMITATION

Template matching techniques applicability is limited mostly by the available computational power, as the identification of big image patterns is time-consuming.

VII. CONCLUSION

There are vast devastating areas in which template matching has wide scope. This paper describes different efficient technique which has been already implemented and have good application rate in their respective fields with their consequences which help authors to get an overview of different template matching algorithm and its applications.

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