ABSTRACT

In most computer vision and image analysis problems, it is necessary to define a similarity measure between two or more different objects or images. Template matching is a classic and fundamental method used to score similarities between objects using certain mathematical algorithms. In this paper, we reviewed the basic concept of matching, as well as advances in template matching and applications such as invariant features or novel applications in medical image analysis. These models have broad applications in image registration, and they are a fundamental aspect of novel machine vision or deep learning algorithms.

Contents

PATTERN MATCHING

1. Introduction

Many applications in image processing and computer vision require finding a particular pattern in an image. This task is referred to as pattern matching and may appear in various forms. Some applications require detection of a set of patterns in a single image, for instance, when a pattern may appear under various transformations or when several distinct patterns are sought in the image. Other applications require finding a particular pattern in several images. The pattern is usually a 2D image fragment, much smaller than the image.

Finding a given pattern in an image is typically performed by scanning the entire image and evaluating the similarity between the pattern and a local 2D window about each pixel. The motivation being to extract some information from the image which is crucial to recognition (and, generally, to other vision tasks).

In the majority of object detection problems in computer vision and image processing, it is often necessary to determine a measure of the similarities between different scenes that have been presented to the system. The detection and recognition of objects in images is a key research topic in the computer vision community. A very common approach to detecting objects and finding the similarity measurement is template matching. Template matching tries to answer one of the most basic questions about an image: if there is a certain object in a given image, and where it is found. The template is a description of that object (and hence is an image itself), and it is used to search the image by computing a difference measure between the template and all possible portions of the image that could match the template. If any of these steps produces a small difference, then it is viewed as a possible occurrence of the object.

2. Methodology

Measures of match and template matching in two- or three-dimensional images require a measure of match between two images that indicates the degree of similarity or dissimilarity between them.

2.1 Featured based approach

A featured-based approach is appropriate when both reference and template images contain more correspondence with respect to features and control points. In this case, features include points, curves, or a surface model to perform template matching. In this category, the final goal is to locate the pair-wise connections between the target or so-called reference and the template image using spatial relations or features. In this approach, spatial relations, invariant descriptors, pyramids, wavelets and relaxation methods play an important role in extracting matching measures.

2.2 Area - based approach

Area-based methods, which are usually known as correlation methods or template matching. This method functions very well when the templates have no strong features with an image, since they operate directly on the pixel values. Matches are measured using the intensity values of both image and template. The matching scores are extracted by calculating squared differences in fixed intensities, correction-based methods, optimization methods and mutual information. In some template matching problems, direct matching between template and target images is impossible. Therefore, the eigenvalue and eigenspace of given images are utilized in template matching. These values provide the details needed to match images under various conditions, such as illumination, color contrast or adequate matching poses.

2.3 Naïve Template Matching:

Nave template matching is one of the basic methods of extracting a given which is identical to the template from the image target. In this approach, with or without scaling (usually without scaling), the target image is scanned by the template, and the similarity measures are calculated. Finally, the positions with the strongest similarities are identified as potential pattern positions. One of the error metrics which is used to calculate the differences between target and template images is the sum of squared differences.

$$SSD = \sum_{x,y} [f(x,y) - t(x-u, y-v)]^2$$

2.4 Image Correlation Matching

In this classic template matching method, the similarity metric between the target and the template is measured. Unlike the nave template matching algorithm, the target and the template might have different image intensities or noise levels. However, those images must be aligned. The similarity metric used in this approach is based on the correlation between the target and the template.

1. **Cross-Correlation:** In image processing, cross-correlation is a measure of the similarity of two images where the images are of different sizes. By sliding the first image (template) over the second image (target), the correlation between the two images is measured. The cross-correlation method is similar in nature to the convolution of two functions. Additionally, cross-correlation of a given signal or image with itself is called auto-correlation

2. **Normalized Cross-Correlation:** Normalized cross-correlation is an updated version of the cross-correlation approach that has been improved for the following two reasons:

a. The results of normalized cross-correlation are invariant to the global brightness changes, and theoretically, the image intensity variations have less effect on this metric compared to the classic method.
b. The correlation value obtained for a given sliding window is normalized to [−1, +1] interval. Therefore, the normalized cross-correlation values for two similar images trend to +1, and those values for two completely different images trend to −1.

Normalized cross-correlation (NCC) is widely used as an operational resemblance measure for template matching problems. NCC is invariant to linear brightness and contrast variations, and its straightforward implementation has expanded its usage for real-time applications. However, this method is still sensitive to rotation and scale changes, which cause some limitations for deformable templates.

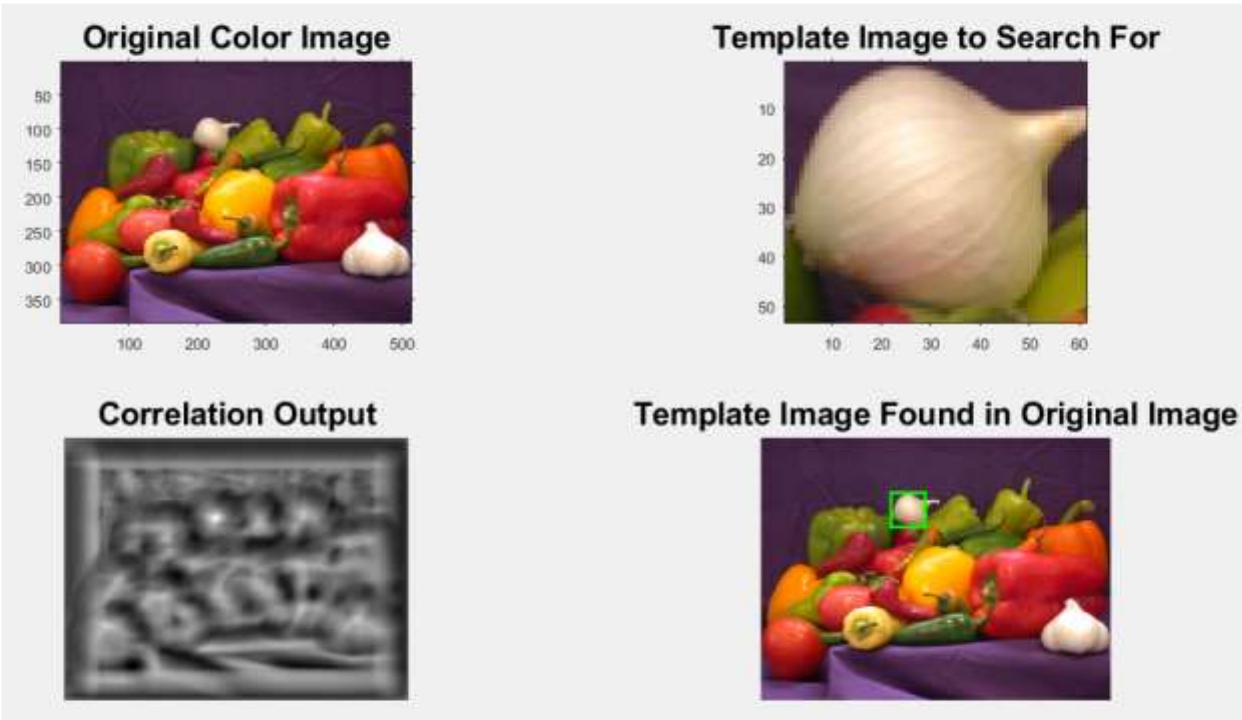
$$NCC = \frac{\sum_{x,y}[f(x,y)-\overline{f}_{u,v}][t(x-u,y-v)-\overline{t}]}{\sum_{x,y}[f(x,y)-\overline{f}_{u,v}]^2\sum_{x,y}[(x-u,y-v)-\overline{t}^2]^{0.5}}$$

3. MATLAB CODE

```
clc;    % Clear the command window.
close all;  % Close all figures (except those of imtool.)
imtool close all;  % Close all imtool figures.
clear;  % Erase all existing variables.
workspace;  % Make sure the workspace panel is showing.
format longg;
format compact;
fontSize = 20;

% Check that user has the Image Processing Toolbox installed.
hasIPT = license('test', 'image_toolbox');
if ~hasIPT
  % User does not have the toolbox installed.
  message = sprintf('Sorry, but you do not seem to have the Image Processing Toolbox.\nDo you want to try to continue anyway?');
  reply = questdlg(message, 'Toolbox missing', 'Yes', 'No', 'Yes');
  if strcmpi(reply, 'No')
    % User said No, so exit.
    return;
  end
end

% Read in a standard MATLAB color demo image.
folder = fullfile(matlabroot, '\toolbox\images\imdemos');
baseFileName = 'peppers.png';
```

```
% Get the full filename, with path prepended.
fullFileName = fullfile(folder, baseFileName);
if ~exist(fullFileName, 'file')
  % Didn't find it there.  Check the search path for it.
  fullFileName = baseFileName; % No path this time.
  if ~exist(fullFileName, 'file')
    % Still didn't find it.  Alert user.
    errorMessage = sprintf('Error: %s does not exist.', fullFileName);
    uiwait(warndlg(errorMessage));
    return;
  end
end
rgbImage = imread(fullFileName);
% Get the dimensions of the image.  numberOfColorBands should be = 3.
[rows columns numberOfColorBands] = size(rgbImage);
% Display the original color image.
subplot(2, 2, 1);
imshow(rgbImage, []);
axis on;
title('Original Color Image', 'FontSize', fontSize);
% Enlarge figure to full screen.
set(gcf, 'units','normalized','outerposition',[0 0 1 1]);

smallSubImage = imcrop(rgbImage, [192 82 60 52]);
subplot(2, 2, 2);
imshow(smallSubImage, []);
axis on;
title('Template Image to Search For', 'FontSize', fontSize);

% Search the red channel for a match.
correlationOutput = normxcorr2(smallSubImage(:,:,1), rgbImage(:,:,1));
subplot(2, 2, 3);
imshow(correlationOutput, []);
title('Correlation Output', 'FontSize', fontSize);

[maxCorrValue, maxIndex] = max(abs(correlationOutput(:)));
[ypeak, xpeak] = ind2sub(size(correlationOutput),maxIndex(1));
corr_offset       =       [(xpeak-size(smallSubImage,2))       (ypeak-
size(smallSubImage,1))];

subplot(2, 2, 4);
imshow(rgbImage);
hold on;
rectangle('position',[corr_offset(1) corr_offset(2) 50 50],...
          'edgecolor','g','linewidth',2);
title('Template Image Found in Original Image', 'FontSize', fontSize);
```

4. RESULT



5. Application of Pattern Matching:

Template matching algorithms contribute in various applications, from security-based to biomedical-based projects. Template matching is a high-level machine vision technique that allows for the identification of those parts of an image that match the given image pattern. Some of its wide-spread applications, including matching object to location and edge detection of images, may be employed to plot a route for mobile robots and in image registration techniques, which also have applications in medical imaging.

The applications of pattern matching are:

- **Face Detection:**

Face detection is a technique that is used to find an arbitrary sub-image representing the human face of a given and global image. This field of computer vision and image processing is broadly used in security applications, video surveillance, tracking, etc., and it may represent all or only a part of such systems. The traditional method of extracting a given face from a global image is to apply a matching algorithm to the target image. One of the most important factors in face detection is a set of human facial features, which plays a crucial role in the process. Over the past decade, a high volume of research has been performed in the field of face detection, which resulted in the determination that the eyes, mouth and nose are the most important features in both face detection and recognition.

- **Eye Detection:**

Eye detection is a prerequisite 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 facial image. The region of face which provides the maximum correlation with the template is the eye region. The method is simple and easy to implement. The effectiveness of the method is demonstrated in both open eyes as well as closed eyes through various simulation results, as shown in Figure.

Fig. Facial images, including a close-up version of an eye extracted from the face at lower right.

- **License Plate Recognition:**

An automatic license plate detection and recognition system is a special form of optical character recognition and has been an active research domain in the image processing field. In a practical sense, template matching is one of the algorithms that can be used to detect licence plates and extract digits or letters from the detected plate. Although the limitations of template matching have been discussed above, the limited styles of license plates, digits and letters in a given region create the opportunity to use template matching in this popular computer vision problem.

The license plate recognition system is a complex image processing application that recognizes the characters on an auto license plate based on the given conditions and situation. The license plate recognition system is installed in many places with multiple purposes, and even law enforcement is using this application to detect speeding vehicles and conduct monitoring and surveillance from a distance.

- **Machine Vision:**

A machine vision system captures images via a camera and analyzes them to produce descriptions of images objects. For example, during inspection in manufacturing industry when the manufactured objects are passed through the camera, the images have to be analyzed online.

- **Computer Aided Diagnosis (CAD):**

CAD helps to assist doctors in making diagnostic decision. Computer assisted diagnosis has been applied in medical field such as X-rays, ECGs, ultrasound images etc.

- **Speech Recognition:**

This process recognizes the spoken information. In this the software in built around a pattern recognition system which recognizes the spoken text ans translated it into ASCII characters which are shown on the screen. In this we can also identify the identity of speaker.

- **Character Recognition:**

This application recognizes both letter and number. In this the optically scanned image is provided as input and alphanumeric characters are generated as output. Its major implication is in automation and information handling. It is also used in page readers, zip code, license plate etc.

- **Manufacturing:**

In this the 3-D images such as structured light, laser, stereo etc is provided as input and as a result we can identify the objects.

- **Fingerprint Identification:**

In this the input image is obtained from fingerprint sensors and by this technique various fingerprint classes are obtained and we can identify the owner of the fingerprint.

6. Conclusion

In this work, the mathematical basics of template matching techniques and various matching algorithms were studied. Additionally, a wide range of template matching applications in image processing, computer vision were reviewed. We also demonstrated template matching algorithms. We concluded that feature-based matching methods should be applied when the structural information matches rather than the intensity information. Furthermore, area-based approaches should be used if they do not have many prominent details and the characteristic information is apparent (color/gray than shape/size). Finally, it is worth remembering that a given template and the input images must have either statistical dependence or intensity similarities. In the case of intensity similarities, the correlation methods can also be used.

References

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