Object Searching with Combination of Template Matching

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Abstract. Object searching is the identification of an object in an image or video. There are several approaches to object detection, including template matching in computer vision. Template matching uses a small image, or template, to find matching regions in a larger image. In this paper, we propose a robust object searching method based on adaptive combination template matching. We apply a partition search to resize the target image properly. During this process, we can make efficiently match each template into the sub-images based on normalized sum of squared differences or zero-mean normalized cross correlation depends on the class of the object location such as corresponding, neighbor, or previous location. Finally, the template image is updated appropriately by an adaptive template algorithm. Experiment results show that the proposed method outperforms in object searching.

Keywords: Object searching · Template matching · Adaptive combination template matching · Normalized sum of squared differences · Zero-mean normalized cross correlation

1 Introduction

Object searching is the process of finding instances of real-world objects such as faces, vehicles, and buildings in images or videos. Object searching algorithms typically use extracted features and learning algorithms to recognize instances of an object category. It is commonly used in applications such as image retrieval, security, surveillance, and automated vehicle parking systems. Moreover, object detection and tracking is considered as an important subject within the area of computer vision. Availability of high definition videos, fast processing computers and exponentially increasing demand for highly reliable automated video analysis have created a new and a great deal for modifying object tracking algorithms. Video analysis has three main steps mainly: detection of interesting moving objects, tracking of such objects from each and every frame to frame and analysis of object tracks to recognize the behavior of the object in the entire video [1]. Several algorithms for object searching have been reported. Mao et al. [2] presented an object tracking approach that integrated two methods consisting of histogram-based template matching method and the mean shift procedure were used to estimate the object location. Choi et al. [3] proposed a vehicle tracking scheme using template matching based on both the scene and vehicle characteristics, including

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background information, local position and size of a moving vehicle. In addition, the template matching [4] is a well-known technique often used in object detection and recognition. This algorithm is a technique in digital image processing for finding small parts of an image which match a template image. 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. This is also due to the simplicity and efficiency of the method. In the next section, we introduce some brief concepts of conventional template matching.

2 Conventional Methods

The conventional template matching methods have been commonly used as metrics to evaluate the degree of similarity (or dissimilarity) between two compared images. The methods are simple algorithms for measuring the similarity between the template image *(T)* and the sub-images of the target image *(I)*. Then, the process will classify the corresponding object.

(a) *Sum of absolute differences (SAD)*

$$R(x,y) = \sum\nolimits_{u,v} |(T(u,v) - I(x+u, y+v)| \tag{1}$$

SAD works by taking the absolute difference between each pixel in T and the corresponding pixel in the small parts of images being used for comparison in I. Absolute differences are summed to create a simple metric of similarity.

(b) *Sum of squared differences (SSD)*

$$R(x,y) = \sum\nolimits_{u,v} (T(u,v) - I(x+u, y+v))^2 \tag{2}$$

(c) *Normalized sum of squared differences (NSSD)*

$$R(x,y) = \frac{\sum_{u,v}(T(u,v) - I(x+u, y+v))^2}{\sqrt{\sum_{u,v} T^2(u,v) \cdot \sum_{u,v} I^2(x+u, y+v)}} \tag{3}$$

SSD and NSSD work by taking the squared difference between each pixel in T and the corresponding pixel in the small parts of images being used for comparison in I. Squared differences are summed to create a simple metric of similarity. The normalization process allows for handling linear brightness variation.

(d) *Normalized cross correlation (NCC)*

$$R(x,y) = \frac{\sum_{u,v}(T(u,v) \cdot I(x+u, y+v))}{\sqrt{\sum_{u,v} T^2(u,v) \cdot \sum_{u,v} I^2(x+u, y+v)}} \tag{4}$$

(e) *Zero-mean normalized cross correlation (ZNCC)*

$$R(x,y) = \frac{\sum_{u,v}(T_*(u,v) \cdot I_*(x+u,y+v))}{\sqrt{\sum_{u,v} T_*^2(u,v) \cdot \sum_{u,v} I_*^2(x+u,y+v)}} \tag{5}$$

where

$$T_*(u,v) = T(u,v) - \bar{T},$$

$$I_*(x+u,y+v) = I(u,v) - \bar{I}$$

NCC works by taking the product of each pixel in T and the corresponding pixel in the small parts of images being used for comparison in I. The normalization process allows for handling linear brightness variation. The main advantage of NCC over the cross correlation is that it is less sensitive to linear changes in the amplitude of illumination in the two compared images. ZNCC is even a more robust solution than NCC since it can also handle uniform brightness variation.

The basic template matching algorithm consists of calculating at each position of the image under examination a distortion function that measures the degree of similarity between the template and image. The minimum distortion or maximum correlation position is then taken to locate the template into the examined image. Many studies on template matching have been reported. Alsaade et al. [5] introduced template matching based on SAD and pyramid structure through compressing both source image and template image. Hager and Belhumeur [6] proposed general illumination models could be incorporated into SSD motion and exhibit a closed-loop formulation for the tracking. Furthermore, Sahani et al. [7] presented object tracking based on two stage search method, whose main application could be tracking aerial target. Maclean and Tsotsos [8] introduced a technique for fast pattern recognition using normalized grey-scale correlation (NCC). Stefano et al. [9] proposed an algorithm for template matching based on the direct computation of the ZNCC function. The algorithm generalized the principle of the BPC technique. Alternative matching algorithms can be found in Refs. [10–12]. However, as far as template matching is concerned, NCC and ZNCC are often adopted for similarity measure as well. The traditional NCC and ZNCC need to compute the numerator and denominator which are very time-consuming. On the contrary, the conventional SAD, SSD, and NSSD are relatively simple.

This paper proposes object searching with combination of template matching. A target image is resized following the object position, then standard robust matching technique NSSD or ZNCC is applied to this image. The applied technique depends on the class of the object location (corresponding, neighbor, or previous location). After that, the object location is identified and the correct positions are updated properly in the whole target image, while the template image is adapted properly. Experiments show that the proposed method outperforms the traditional search algorithms.

3 Proposed Method

The proposed method is initially motivated by Chantara's work [13] based on matching efficiency. Based on Chantara's work, the proposed method adapts an adaptive template matching to enhance the matching accuracy. The contribution of the proposed method is to increase the matching performance.

3.1 Partition Search Area

A partition search area reallocates the target image. A proper size of the target image relates to the previous interested object position as shown in Fig. 1. An algorithm result is illustrated in Fig. 2.

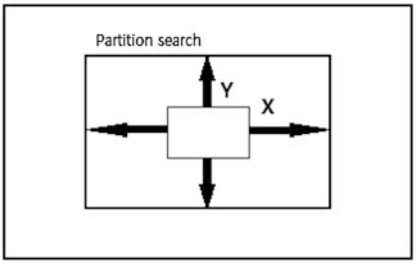

Fig. 1. Partition search area

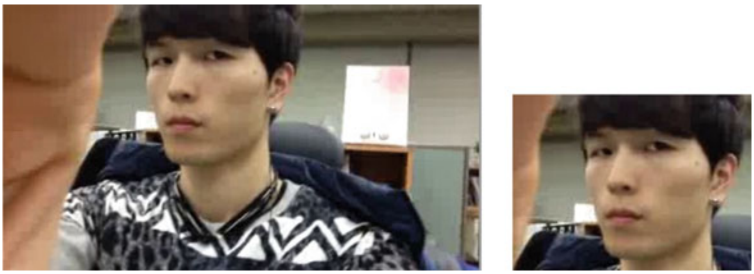

Fig. 2. (Left) Original target image, (Right) reallocated target image

When the appropriate target image is provided as shown in Fig. 2 (Right), we perform object detection with template matching (NSSD or ZNCC). The result data of matching algorithm provide the location of the corresponding object (CL) in the target image. Other neighbor results and locations (NLs), which are in a limit of a threshold value, can also be found.

3.2 Object Identification

We apply the result data from the previous subsection to locate the suitable location of interested object (OL) in a full target image (Table 1).

Assume: The previous object position (PP) is reserved in a memory buffer.

Table 1. Object identification method

Option	Process
Option 1	*Condition:* CL is the closest of PP.
	Process:
	1. OL = CL
	2. Flag parameter = 0
Option 2	*Condition:* NLs is the closest of PP.
	Process:
	1. OL = the closest of NLs
	2. Flag parameter = 1
Option 3	*Condition:* CL is not option 1 and 2.
	Process:
	1. OL = PP
	2. Flag parameter = 2

Table 2. Adaptive combination template matching method

Flag status	Process
Flag = 0	*Condition:* OL = CL
	Process:
	1. Previous template = Current template
	2. Current template = Original template
Flag = 1	*Condition:* OL = the closest of NLs
	Process:
	1. Previous template = Current template
	2. Current template = Object template
Flag = 2	*Condition:* OL = PP
	Process:
	1. Previous template = Current template
	2. Current template = Original template
	3*. Toggle NSSD ⇔ ZNCC

3.3 Adaptive Combination Template Matching

The flag parameter is considered to examine a suitable template image. The process also switches the matching algorithms between NSSD and ZNCC when the condition is the previous position of the object uses as the object location (Table 2).

4 Experiment Results

In this section, we present the efficient performance of the proposed method. The experiments are performed to examine the matching accuracy. The system executes on a PC with an Intel (R) Core (TM) i7-3930 K CPU 3.20 GHz, 16.0 GB RAM and operating system of Windows 8.1. A 101 × 98 sized template image is used to match in target image sequences which is a size of 426 × 240 pixels, as shown in Fig. 3. Furthermore, other template image and the related target image contain different sizes and different illuminations is illustrated in Fig. 4.

Fig. 3. (Left) Target image, (Right) template image

Fig. 4. (Left) Target image 768 × 576 pixels, (Right) template image 40 × 75 pixels

Figures 5, 6 and 7 demonstrate the results of each option in Subsects. 3.2 and 3.3. An illumination in each figure shows the outcome of the matching method with the

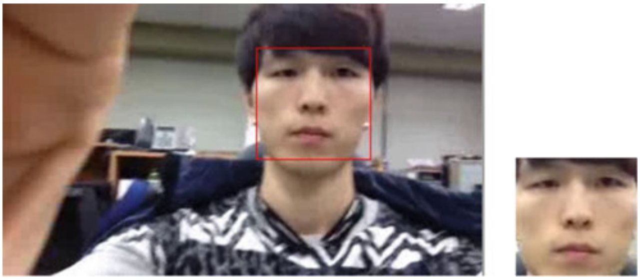

Fig. 5. Option 1: (Left) object location, (Right) adaptive template image

Fig. 6. Option 2: (Left) object location, (Right) adaptive template image

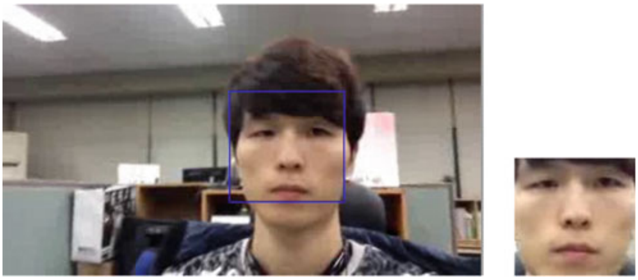

Fig. 7. Option 3: (Left) object location, (Right) adaptive template image

Table 3. Comparison of the PSNR values

Image Sequence	PSNR Values (dB)				
	SAD	NSSD	ZNCC	Chantara's Method	Proposed Method
Walking	16.48	16.53	16.49	17.25	18.67

Image Sequence	PSNR Gains (dB)			
	$\Delta PSNR_{PS}$	$\Delta PSNR_{PN}$	$\Delta PSNR_{PZ}$	$\Delta PSNR_{PC}$
Walking	+2.19	+2.14	+2.18	+1.42

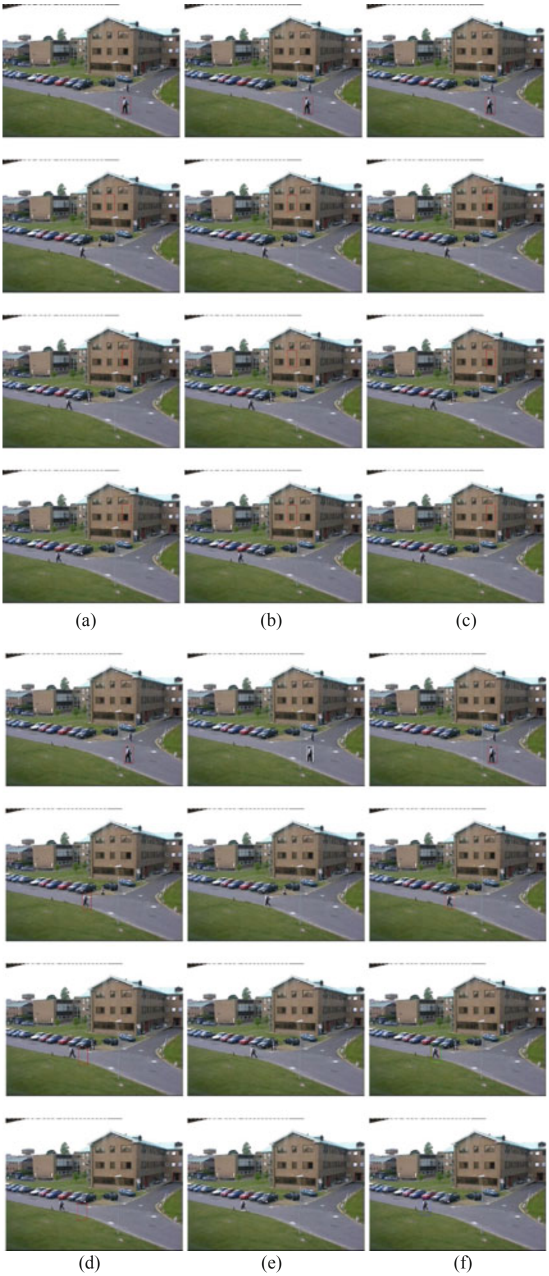

Fig. 8. The experiment results: (a) SAD method, (b) NSSD method, (c) ZNCC method, (d) Chantara's [13] (e) ground truth [14], (f) proposed method, the results are captured in different frames

Table 4. Comparison of the computational time

Image sequence	Computational time (ms)				
	SAD	NSSD	ZNCC	Chantara's method	Proposed method
Face	96.57	97.06	100.72	97.29	90.98
Walking	378.26	380.83	429.03	418.04	57.77

position of involved object and the updated template. In the third option, the matching method is switched between NSSD and ZNCC algorithms.

To illustrate the performance of the proposed algorithm, the template matching algorithm like SAD, NSSD and ZNCC were compared. The results are shown in Fig. 8, Table 3 lists PSNR values for the proposed method and the three above-mentioned methods, the PSNR gain is defined as Eq. 6 and Table 4 presents the computational time of the algorithms. The proposed method outperforms the conventional methods.

$$\Delta PSNR_{PR} = PSNR_{Proposedmethod} - PSNR_{Referencemethod} \tag{6}$$

5 Conclusion

In this paper, we proposed an object searching with combination of template matching. The method provides the proper object location in a target image. We apply a partition search to give the appropriate target image for the template matching algorithm. The process reduces the computing time. The proper target image has been searched the interested object by an adaptive combination template matching. The method identifies the object accurately, then updates the suitable template image and switches the matching algorithms between NSSD and ZNCC when the previous position of the object uses as the object position. This process increases an accurate object location on the target image. Based on the experiment results, we can analyze that the proposed method has more efficient than the conventional methods like SAD, NSSD and ZNCC. Moreover, a comparison of the interested object in the target image provides that the proposed method is outperformance.

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