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Object Tracking using Adaptive Template Matching

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** Regular Paper*

Abstract**:** Template matching is used for many applications in image processing. One of the most researched topics is object tracking. Normalized Cross Correlation (NCC) is the basic statistical approach to match images. NCC is used for template matching or pattern recognition. A template can be considered from a reference image, and an image from a scene can be considered as a source image. The objective is to establish the correspondence between the reference and source images. The matching gives a measure of the degree of similarity between the image and the template. A problem with NCC is its high computational cost and occasional mismatching. To deal with this problem, this paper presents an algorithm based on the Sum of Squared Difference (SSD) and an adaptive template matching to enhance the quality of the template matching in object tracking. The SSD provides low computational cost, while the adaptive template matching increases the accuracy matching. The experimental results showed that the proposed algorithm is quite efficient for image matching. The effectiveness of this method is demonstrated by several situations in the results section.

Keywords**:** Template matching, Object tracking, Normalized cross correlation, Sum of squared difference, Pattern recognition

1. Introduction

Nowadays, video surveillance systems are being installed worldwide in many different sites, such as airports, hospitals, banks, railway stations, and even at homes. Surveillance cameras help a supervisor to oversee many different areas in a single room and to quickly focus on abnormal events taking place in the controlled space. Intelligent video monitoring expresses a fairly large research direction that is applied in different fields. On the other hand, several question arise, such as how can the intensity of the objects tracking with occlusion be improved. When an occlusion occurs, some objects are partially or totally invisible. As shown in Fig. 1, this phenomenon makes it difficult to localize the real object target accurately.

Fig. 1. Shading real target by other objects.

2. Object Tracking

Object tracking in real-time environment is a different task in different computer vision applications. Object tracking consists of an estimation of the trajectory of moving objects in the sequence of frames generated from a video [1].

Most tracking algorithms assume that the object motion is smooth with no abrupt changes to simplify tracking [2]. For example, the traditional color histogram Mean Shift (MS) algorithm only considers the object's color statistical information, and does not contain the object's space information, so when the object color is close to the background color, or the object's illumination is changed, the traditional MS algorithm easily causes inaccurate object tracking or it can be lost. Therefore, Mao et al. [3] proposed an object tracking approach that integrated two methods consisting of histogram-based template matching method, and the mean shift procedure was used to estimate the object location.

Tracking methods also are related to a traffic surveillance systems. Choi et al. [4] proposed a vehicle tracking scheme using template matching based on both the scene and vehicle characteristics, including background information, local position and size of a moving vehicle. Alternative object tracking can be found in Refs. [1, 5, 6].

On the other hand, these basic tracking algorithms have weak intensity when the other object occludes the real source image. Automation of the computer object tracking is a difficult task. Therefore, to solve these kind of problems, this paper proposes the 'template matching' object tracking method. Before explaining the algorithm, some brief concepts of 'template matching' are introduced.

3. Template Matching

Template matching is the process of finding the location of a sub image, called a template, inside an image. A number of methods for identical images can be used. This section discusses the template matching application for matching a small image, which is a part of a large image. Once a number of corresponding templates are found, their centers can be used as the corresponding control points to determine the matching parameters. Template matching involves comparing a given template with windows of the same size in an image and identifying the window that is most similar to the template.

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. Typical distortion measures are the Sum of Absolute Differences (SAD) [7, 8] and the Sum of Squared Differences (SSD) [9]. On the other hand, as far as template matching is concerned, the Normalized Cross Correlation (NCC) [10] is often adopted for similarity measure. Essannoun et al. [11] proposed a fast frequency algorithm to speed up the process of SAD matching. They used an approach to approximate the SAD metric by a cosine series, which could be expressed in correlation terms. Furthermore, Hel-Or and Hel-Or [12] proposed a fast template matching method based on accumulating the distortion on the Walsh-Hadamard domain in the order of the associated frequency using SSD.

The traditional NCC needs to compute the numerator and denominator, which is a very time-consuming. Lewis [7] employed the sum table scheme to reduce the computation in the denominator. Although the sum table scheme could reduce the computation of the denominator in NCC, it was essential to simplify the computation

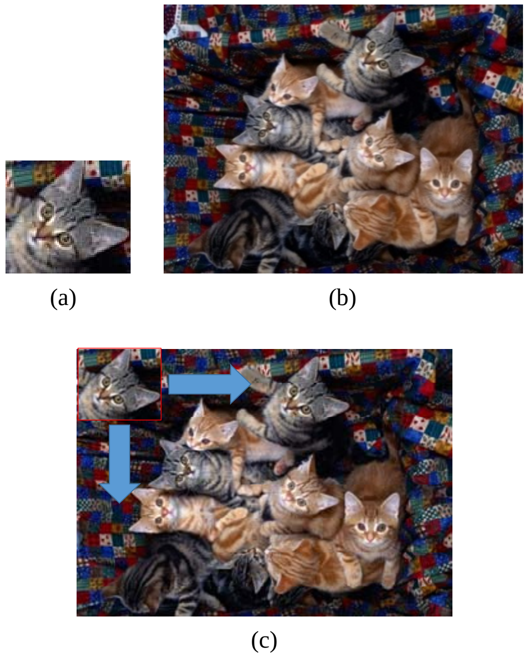


Fig. 2. (a) Template image, (b) Source image, (c) Window sliding and matching.

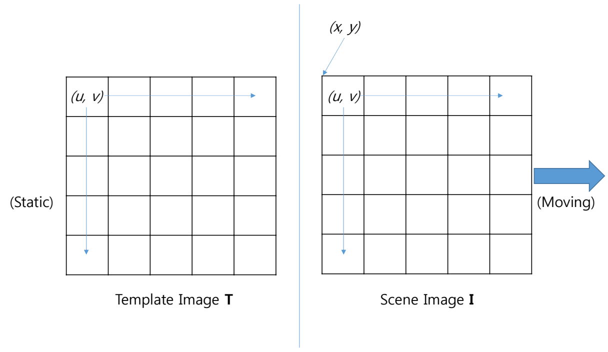


Fig. 3. Matching procedure.

involved in the numerator of NCC. Wei and Lai [13] proposed a fast pattern matching algorithm based on NCC criterion by combining adaptive multilevel partition with the winner update scheme to achieve a very efficient search. Alternative similarity measures can be found in Refs. [14-17].

In Fig. 2, to identify a matching area, the method needs to compare a template image against a source image by sliding it. By sliding the template, the process can measure the similarity between the template image and a region in the source image. At each location, a metric is calculated so it represents how similar the patch is to that particular area of the scene image. The process then finds the maximum or the minimum location in the resulting image depending on the measurement.

3.1 Matching Methods

Fig. 3 shows the matching procedure. Here, u and v represent a horizontal and vertical position in the kernel, respectively, and x and y correspond to a position of the kernel. The procedure can calculate a result pixel using various matching methods. Eqs. (1)-(4) show the matching methods.

1. Sum of Squared Difference (SSD)

$$R(x,y)=\sum_{u,v}\left(T(u,v)-I(x+u,y+v)\right)^2 \quad (1)$$

2. Normalized Sum of Squared Difference (NSSD)

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

3. Cross Correlation (CC)

$$R(x,y)=\sum_{u,v}\left(T(u,v)\cdot I(x+u,y+v)\right) \quad (3)$$

4. Normalized Cross Correlation (NCC)

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

For SSD or NSSD, the process needs to find the minimum value in the resulting image. Otherwise, if using the CC or NCC, the process needs to find the maximum value in the result.

This paper introduces object tracking using an adaptive template matching technique. In this technique, SSD was used to measure the similarity between a template image and source image. The finest object location was selected in the source image. Finally, the template image, which is an adapted template image, was updated.

4. Proposed Methods

The objective of the proposed method is to reduce a computational cost and increase accurate matching. As a similarity measure, the SSD is the most popular and widely used for several applications. NCC is more robust against illumination changes than SSD; nevertheless, NCC is more time-consuming than SSD.

The following three key steps are involved in implementing of the proposed method.

- Detection of interesting object,
- Tracking of object from frame to frame,
- Updating of suitable template.

4.1 Template Matching

The SSD is a simple algorithm for measuring the similarity between the template image (T) and sub-images in the source image (I). It works by taking the squared difference between each pixel in T and the corresponding pixel in the sub-images used for the comparison in I. These squared differences are summed to create a simple metric of similarity. Assume a 2-D $m\times n$ template, $T(x,y)$ is matched within the source image, $I(x,y)$, of size $p\times q$, where ($p>m$ and $q>n$). For each pixel location (x,y) in the image, the SSD distance is calculated as follows:

$$R(x,y)=\sum_{u,v}\left(T(u,v)-I(x+u,y+v)\right)^2 \quad (5)$$

The smaller the distance measured SSD at a particular location, the more similar the local sub-image found is the searched template. If the distance SSD is zero, the local sub-image is identical to the template. The minimum distance provides the location of the corresponding object (CL) in the source image. Other small distances and locations (SLs), which are less than the threshold value, can also be found. These values will be proposed in a next subsection.

4.2 The best object location

This subsection proposes a method for locating the position of an interesting object in an image (OL). The aim of this process was to identify an appropriate coordinate that finds in the source image.

Assumption: The previous location of object (PL) is stored in a memory buffer.

Condition 1:

If the CL is the nearest of PL then,
Set OL = CL, and assign Location flag (FL) = 1

Condition 2:

If the SLs are the nearest of PL then,
Set OL = the nearest of SLs, and assign the FL = 0

Condition 3:

If the CL doesn't match in Condition 1 and 2 then,
Set OL = PL, and assign FL = 0

Fig. 4 shows a flowchart of a method for finding the best object location following the above-mentioned.

4.3 Adaptive Template Matching

In this subsection, the FL parameter from section 4.2 is considered to determine an appropriate template image.

Location flag = 0, it means that

- The OL is the SLs or PL.
- Assign the previous template with the current template.
- Update the current template with the current object template.

Location flag = 1, it means that

- The OL is the CL from the SSD method.
- Assign the previous template with the current template
- Update the current template with the original template.

The result image

- Green box is the PL position in the source image.
- Red box is the OL position in the source image.

The overall actions are described more detail in Fig. 5.

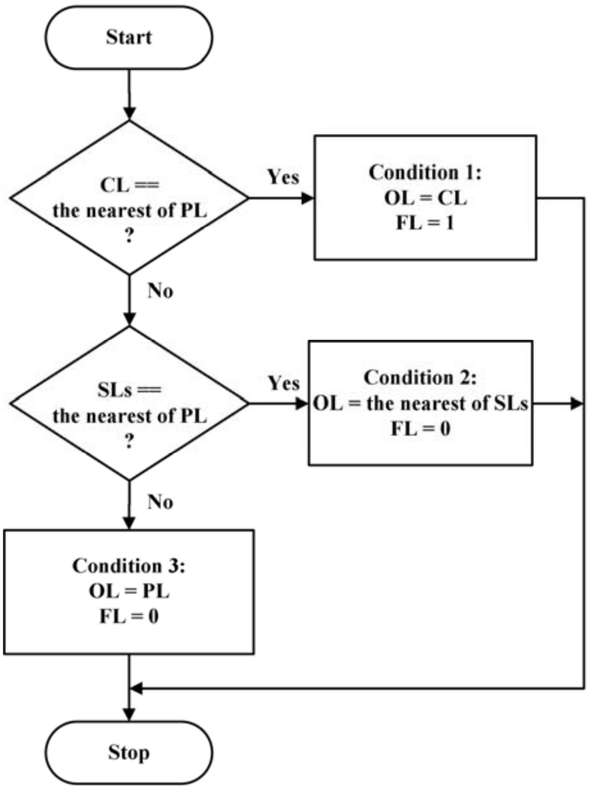


Fig. 4. Algorithm to find the best object location.

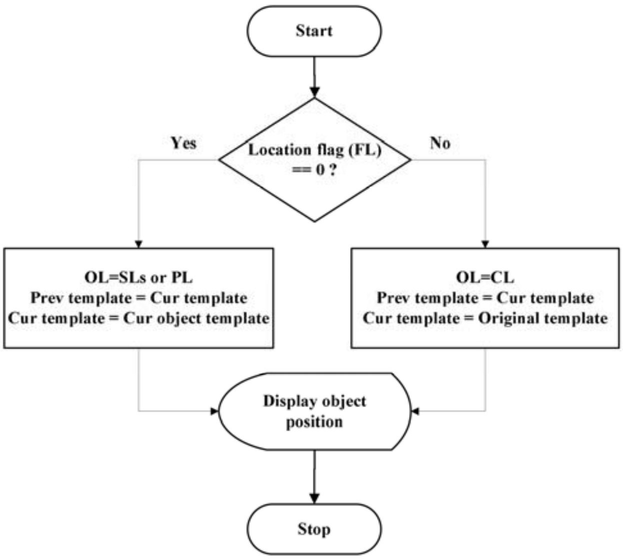


Fig. 5. Algorithm to update template.

5. Experiment Results

This section shows the advantage of the proposed method to full track an interested object. Experiments were performed to examine the matching accuracy. A template image of 27x67 pixels (Fig. 4(b)) was used to match in a source image the sequences of size of 352x288 pixels, as shown in Fig. 4(a).

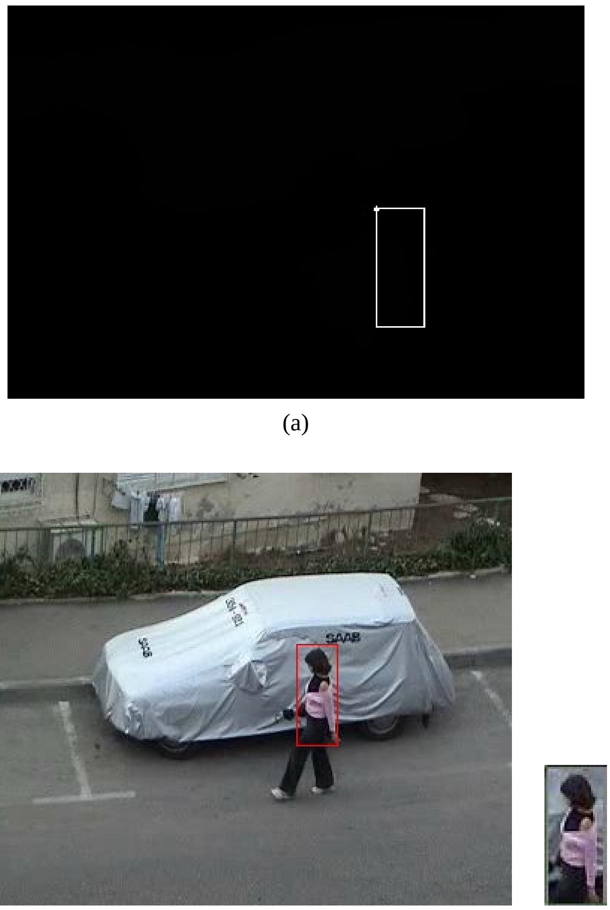
Figs. 7-9 illustrate each condition that is explained in section 4.2. An illumination of (a), (b), and (c) in each figure shows the result of the SSD method, the position of involved object and the updated template respectively.

To illustrate the performance of the proposed algorithm,

(a) (b)

Fig. 6. (a) Source image, (b) Template image.

Condition 1:



(a)

(b) (c)

Fig. 7. Condition 1 (a) SSD result, (b) Object location, (c) Update the current template with the original template.

Condition 2:

(a) (b) (c)

Fig. 8. Condition 2 (a) SSD result with the SLs, (b) Object location shows the PL in a green box and the current location in a red box, (c) Update the current template with the current object template.

Condition 3:

(a) (b) (c)

Fig. 9. Condition 3 (a) SSD result with the SLs, (b) Object location shows the current location with the PL in a green box, (c) Update the current template with the current object template.

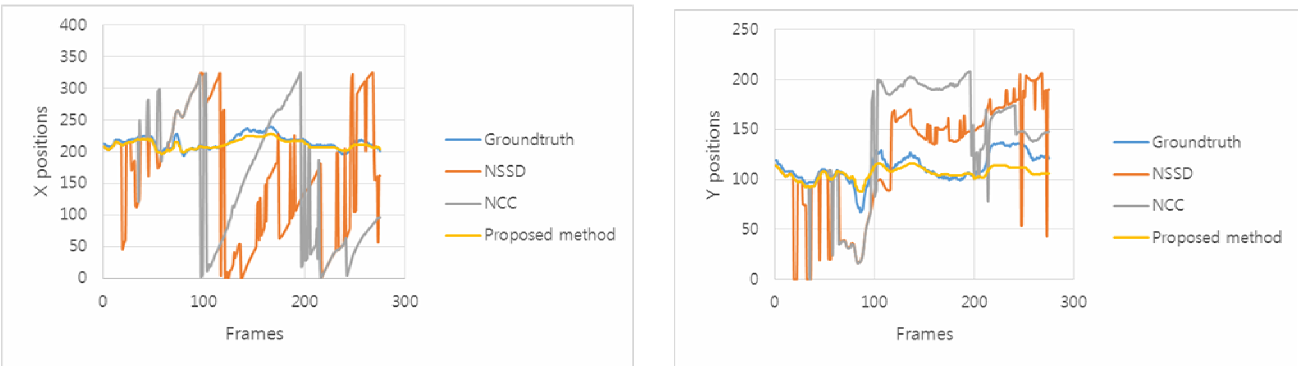
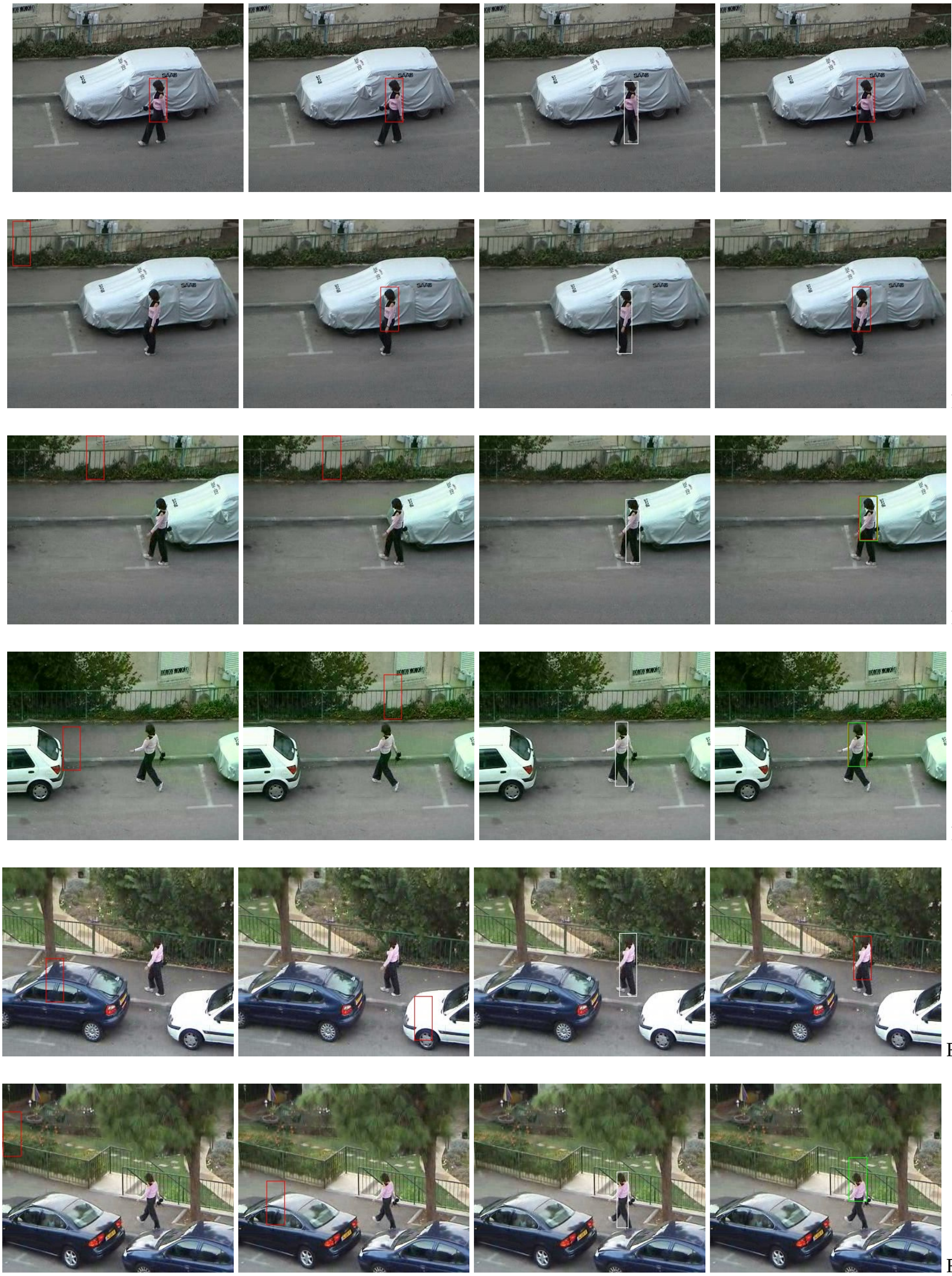


Fig. 10. Object's positions on consecutive frame sequence.

the template matching algorithm like the NSSD and NCC were compared. The result is shown in Fig. 11. Fig. 10 shows x and y object positions curves on a consecutive image frames. The proposed method outperforms the two conventional methods.

In addition, other experiment samples consisting of



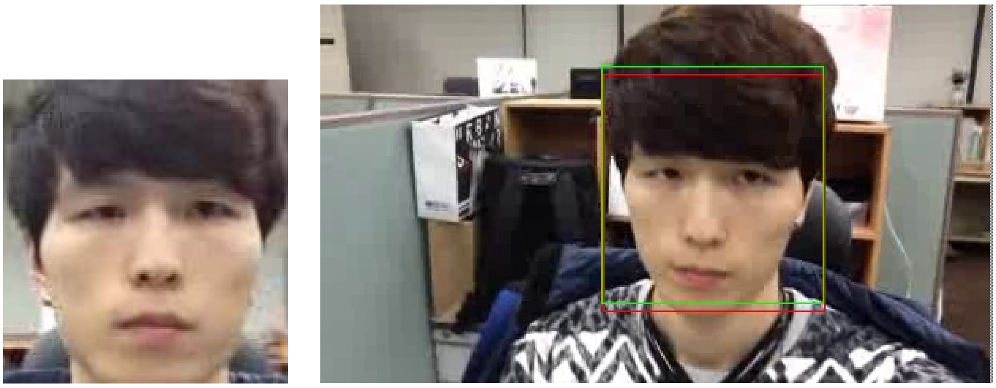
F.1 F.10 F.35 F.64 F.177 F.250

(a) (b) (c) (d)

Fig. 11. Experiment result (a) NSSD, (b) NCC, (c) Ground truth [18], (d) Proposed method, the results are captured at 1st, 10th, 35th, 64th, 177th, and 250th frame respectively.

(a) (b)

Fig. 12. Result related to condition 3 (a) Template image, (b) Object tracking.



(a) (b)

Fig. 13. Result related to condition 2 (a) Template image, (b) Object tracking.

(a) (b)

Fig. 14. Result related to condition 1 (a) Template image, (b) Object tracking.

three source images and their templates with the proposed algorithm were implemented. These samples contain different sizes and different illuminations. Figs. 12-14 show the outcomes.

6. Conclusion

This paper proposed an object tracking using an adaptive template matching algorithm. The adaptive template matching provides the proper object location in a source image. The SSD uses a small number of operations for a similarity purpose. Therefore, the proposed method reduces the computational cost and increases the accuracy. Based on the experiment results, the proposed method is more efficient than the conventional methods, such as NSSD and NCC. Furthermore, a comparison of the identification object in the source image confirmed that the proposed method outperforms the conventional methods.

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