

Convergence Control of Moving Object using Opto-Digital Algorithm in the 3D Robot Vision System

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Abstract

In this paper, a new target extraction algorithm is proposed, in which the coordinates of target are obtained adaptively by using the difference image information and the optical BPEJTC(binary phase extraction joint transform correlator) with which the target object can be segmented from the input image and background noises are removed in the stereo vision system. First, the proposed algorithm extracts the target object by removing the background noises through the difference image information of the sequential left images and then controlls the pan/tilt and convergence angle of the stereo camera by using the coordinates of the target position obtained from the optical BPEJTC between the extracted target image and the input image. From some experimental results, it is found that the proposed algorithm can extract the target object from the input image with background noises and then, effectively track the target object in real time. Finally, a possibility of implementation of the adaptive stereo object tracking system by using the proposed algorithm is also suggested.

Keywords : convergence, pen/tilt, stereo visionoptical BPEJTC , convex hull filter.

1. Introduction

To improve the efficiency of remote work, there are many 3D image system studies using visual information. Especially, studies on the development of 3D imaging system resembling the structure of a human eye are lively stereo vision system which capture moving images exactly like the human eye. The 3D image system is composed of stereo camera for inputing image and monitor for outputting cubic image for observer. The observer is able to feel 3D image due to the difference in both eyes from stereo camera using two cameras that are parallelly disposed like the human eye. However, the disparity can also cause the fatigue. Therefore, it is necessary for stereo disparity to be maintained as zero.

In this paper, we propose a new stereo target tracking algorithm that control convergence of moving object in the stereo vision system. The proposed algorithm, first, extract the target object by removing the background noises through the difference image information of the sequential left images and then, controls the pan/tilt and convergence angle of the stereo camera by using the coordinates of the target position obtained from the optical BPEJTC which was excuted between the extracted target image and the input image. Also, we propose a novel 3D vision system to detect and segment the moving object adaptively through controlling the pan/tilt system of stereo cameras by using optical BPEJTC(Binary Phase Extraction joint transform correlator).

2. Convergence Control of a Moving Target Object

Control of the convergence angle is noted that

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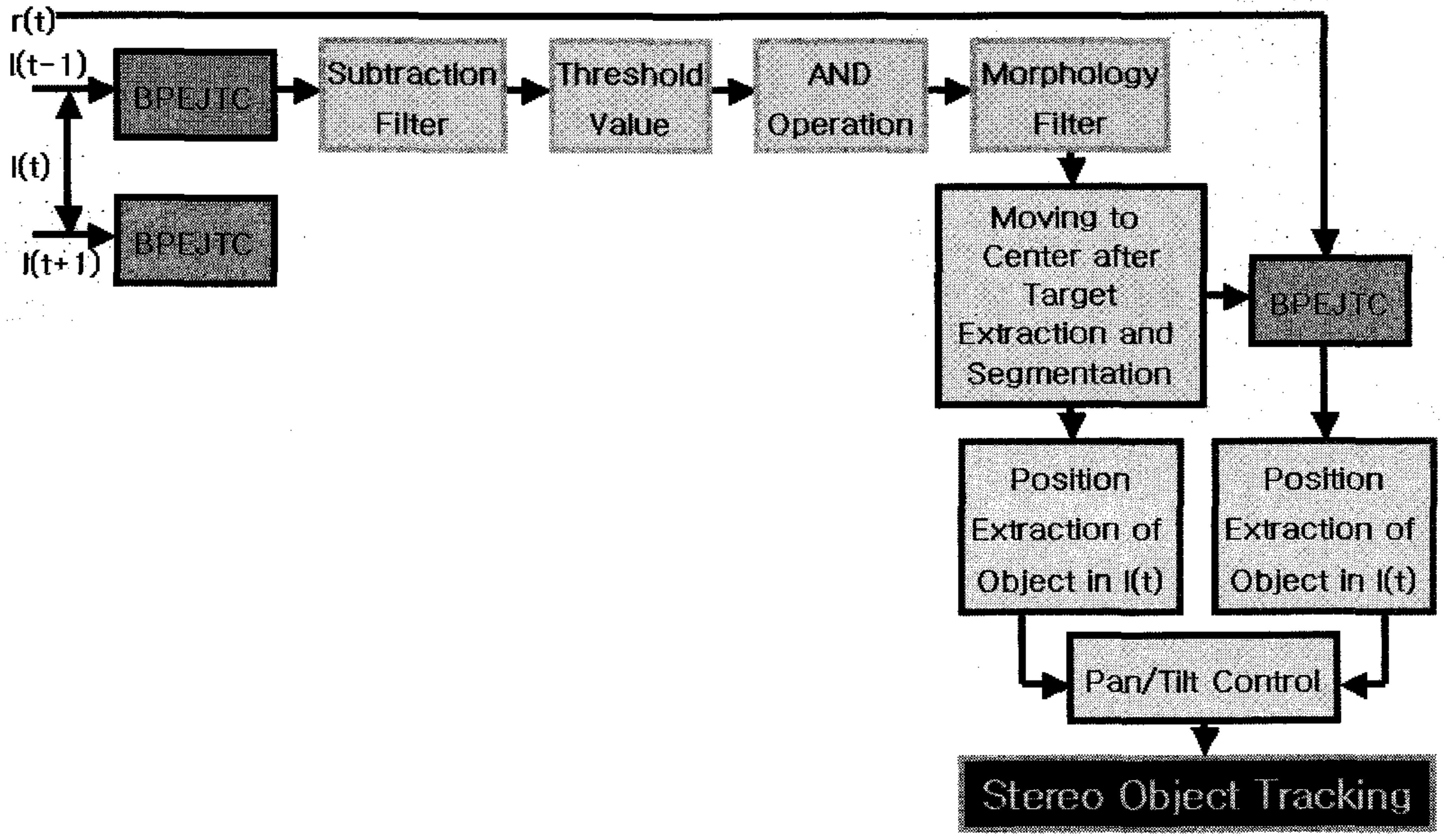

Fig. 1. Block diagram of the proposed convergence control algorithm.

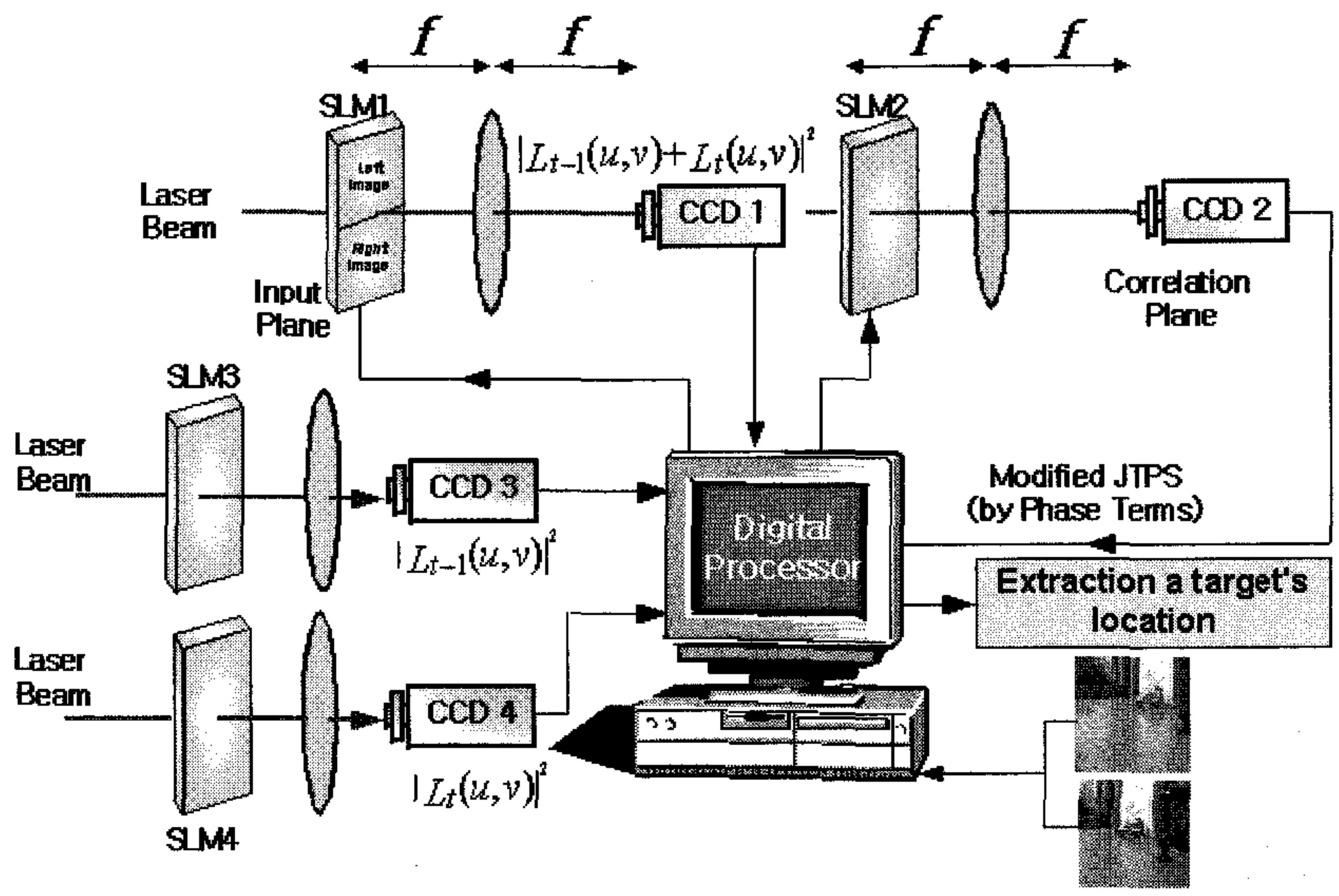

Fig. 2. Block diagram of the optical BPEJTC system.

stereo disparity would be agreed among the observing left and right cameras for the moving target. Generally, it is possible to extract the position data for the left and right images using the correlation method by obtaining a change of relative position between two incoming images.

Fig. 1 shows the overall flowchart of the proposed stereo object tracking algorithm of this paper.

This paper suggests a new method to match the backgrounds between the reference frame and the moving target frame, after finding out the relative moving speed and the direction of camera by calculating the correlation peak value from three sequential frames by using the optical BPEJTC.

In optical BPEJTC input plane, the image on the spatial light modulator (SLM1) is Fourier-transformed by the lens, as shown in Fig.2, and detected on CCD1 in the form of JTPS (joint transform power spectrum).

The optical power spectrum distribution of the JTPS, which was Fourier-transformed between the reference image [$l_{t-1}(x, y)$] and the comparing image [$l_t(x, y)$], can be expressed as Eq. (1).

$$
\begin{aligned}
E_{JTC}(u,v) &= |l(u,v)|^2 \\
&= |l_{t-1}(u,v)|^2 + |l_t(u,v)|^2 \\
&\quad + l_{t-1}(u,v)\exp[j\Phi_L(u,v)]l_t(u,v)\exp[-j\Phi_R(u,v)] \\
&\quad \exp[-j2\pi[u(\Delta x_l - \Delta x_r) + v(\Delta y_l - \Delta y_r + w)] \\
&\quad + l_t(u,v)\exp[-j\Phi_L(u,v)]l_t(u,v)\exp[j\Phi_R(u,v)] \\
&\quad \exp[j2\pi[u(\Delta x_l - \Delta x_r) + v(\Delta y_l - \Delta y_r + w)]
\end{aligned} \tag{1}
$$

The block diagram of the optical BPEJTC system for the $l(t-1)$ image and the $l(t)$ image is shown in Fig.2.

Therefore, since the self-correlating components, $|l_{t-1}(u,v)|^2$ and $|l_t(u,v)|^2$, can be obtained from the CCD3 and CCD4, as shown in Fig. 2, a new JTPS can be derived by eliminating two terms of $|l_{t-1}(u,v)|^2$ and $|l_t(u,v)|^2$ from the conventional optical JTPS as Eq. (2),

$$
\begin{aligned}
E_{NEW}(u,v) &= E_{JTC}(u,v) - |l_{t-1}(u,v)|^2 - |l_t(u,v)|^2 \\
&= 2|l_{t-1}(u,v)|\cdot|l_t(u,v)|\cos[(\Delta x_l - \Delta x_r)u \\
&\quad + (\Delta y_l - \Delta y_r + w)v + \Phi I_{l(t-1)}(u,v) - \Phi I_{l(t)}(u,v)]
\end{aligned} \tag{2}
$$

The last line of Eq. (2) is expressies the optical JTPS of the correlator when the spatial matching filter is used as a cosine value.

Eq. (3) is the result of using revised JTPS as the SLM2's input and obtaining the correlating result on a correlation plane by inverse Fourier transform

$$
\begin{aligned}
C_{BPEJTC}(x,y) &= \Im^{-1}\{E_{BPEJTC}(u,v)\} \\
&= [l_{t-1}(x,y) \otimes l_t(x,y)] * \\
&\quad \delta[x + (\Delta x_{l(t-1)} - \Delta x_{l(t)}),\ y + (\Delta x_{l(t-1)} - \Delta x_{l(t)} + w)] \\
&\quad + [l_t(x,y) \otimes l_{t-1}(x,y)] * \\
&\quad \delta[x - (\Delta x - \Delta x_{l(t-1)}),\ y - (\Delta x_{l(t-1)} - \Delta x_{l(t)} + w)]
\end{aligned} \tag{3}
$$

Here, $\otimes$ and * denote the correlation and convolution operator, respectively. Equation (3) is detected as the correlation peak point on the correlation plane of Fig. 2 by CCD2. Therefore, through digital calculation, the location coordinates $(\Delta x_r, \Delta y_r)$ of tracking object on the right image could be obtained from the correlation peak point.

The moving factor of the target object from two images can be obtained by applying a subtraction filter and AND operation, and then projecting on target image with deciding mask by using morphology filter. The moving target can be segmented through these procedures. In this paper, the sequential repeated process of convex hull filter and closing techniques are applied to get the target area in the target image.

By applying the convex hull filter and closing techniques on the image entirely, we can make out not only the boundary of the target area smooth but also create a target mask.

To get the position information of the tracking object, the distance value is needed to be obtained, which is calculated by a relative distance between two objects through correlation of the optical BPEJTC between the reference image and the left image and these values are used for the pan-tilt control data of the left-side camera.

The value of Eq.(4) is detected on CCD2 as the correlation peak point on the correlation plane of Fig. 2. This peak point is the relative distance between the reference image and the left image on the coordinates.

$$
\begin{aligned}
&Edge[I_r(x,y)] = F^{-1}\{ph[I_R(u,v)]\} \\
&Where, Ph[I_R(u,v)] = \frac{I_R^*(u,v)}{I_R(u,v)} = 1\cdot\exp[-j\phi_{I_n}(u,v)]
\end{aligned} \tag{4}
$$

Consequently, through digital calculation, the location coordinates $(\pm\Delta x_l, \pm\Delta y_l)$ of the tracking object on the left image could be obtained from the correlation peak point. In a similar manner, the location coordinates $(\pm\Delta x_r, \pm\Delta y_r)$ of tracking object on the right image could be obtained through the optical BPEJTC execution between the reference image and the right image. Therefore, the stereo object tracking is possible if the stereo cameras pan/tilt is controlled with the left and right cameras that control values $(\pm\Delta x_l, \pm\Delta y_l)$ and $(\pm\Delta x_r, \pm\Delta y_r)$.

3. Stereo Tracking Experiments and Results

Fig. 4 shows the 3 frames of the left input image among the 50 frames used in the experiment. The

Table 1. Translation rate between frames.

	Background distance > Target distance		Background distance < Target distance	
1, 2 th image	Correlation position	(117, 116)	Correlation position	(104, 123)
1, 2 th image	Distance component	$\Delta x = -16,\ \Delta y = 5$	Distance component	$\Delta x = -5,\ \Delta y = 0$
3, 4 th image	Correlation position	(164, 96)	Correlation position	(96, 117)
3, 4 th image	Distance component	$\Delta x = 17,\ \Delta y = 16$	Distance component	$\Delta x = 0,\ \Delta y = 1$

Table 2. Extraction of location's coordinate for tracking object.

	Frame 1		Frame 2		Frame 3		Frame 4	
Coordinate	Left	Right	Left	Right	Left	Right	Left	Right
(x, y)	(-30, -6)	(-35, -8)	(-37, -13)	(-45, -13)	(-46, -22)	(-57, -23)	(-66, -23)	(-69, -22)

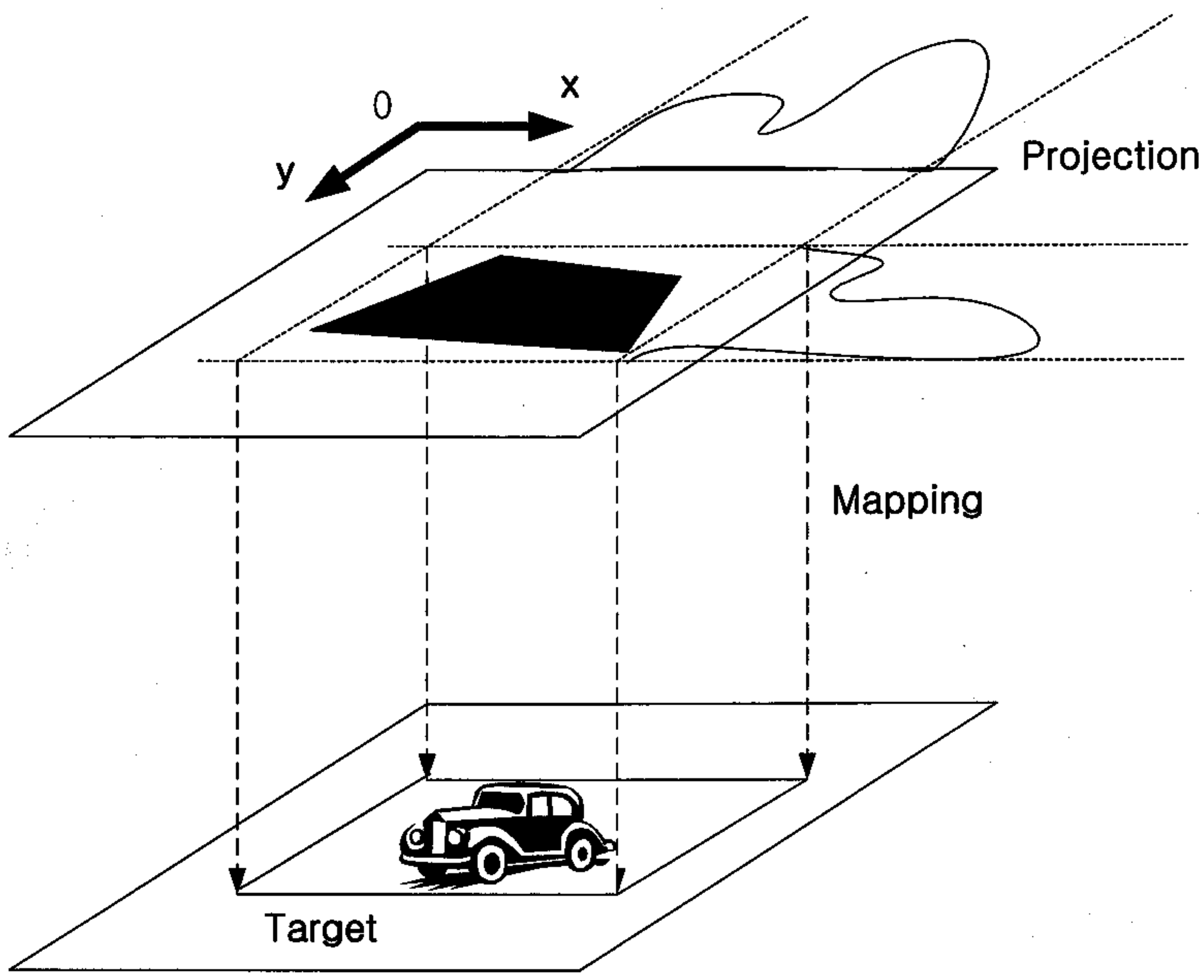

Fig. 3. Projection process for target segmentation.

position of the maximum correlation peak values and the moving displacement factor of camera, which have been calculated from the correlation of inputted images in consecutive comparing with the reference image, are shown in Table 1. Because the camera displacement is larger than the target displacement, the displacement

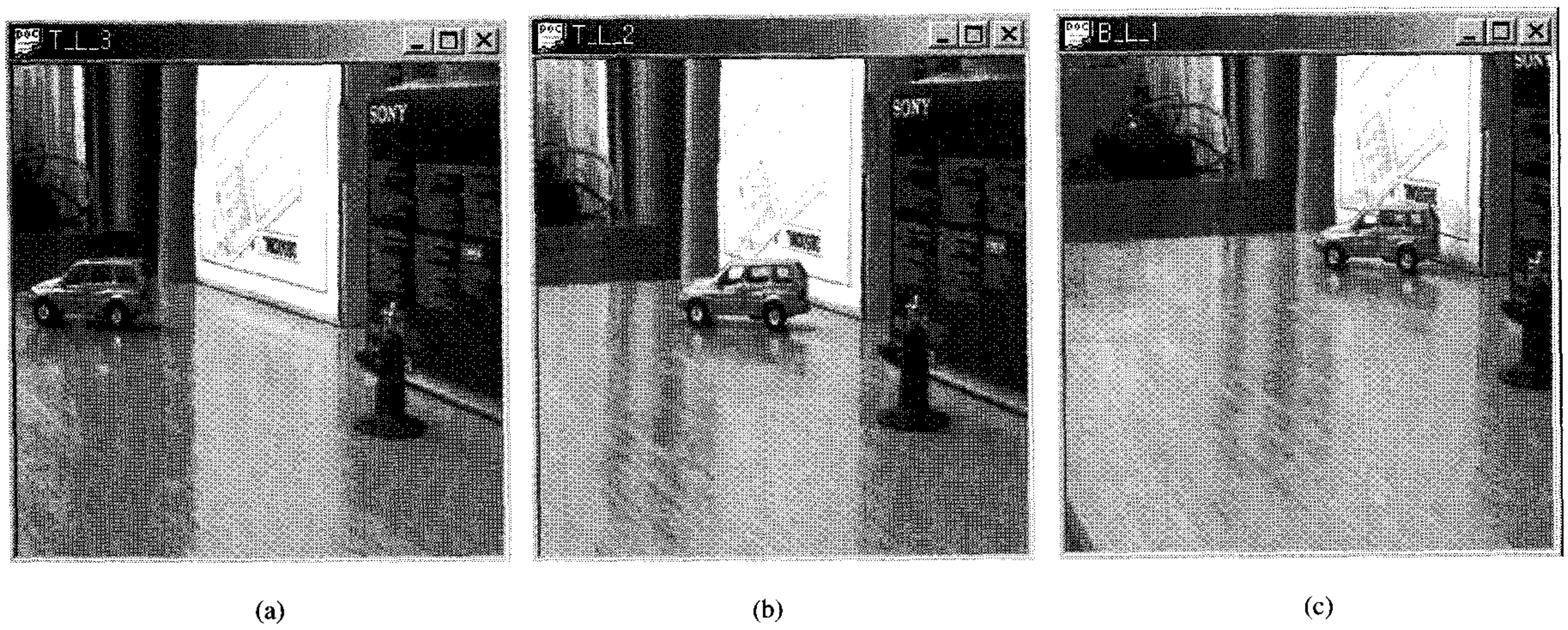

Fig.4. Left input image (a) I(t+1), (b) I(t) and (c) I(t-1).

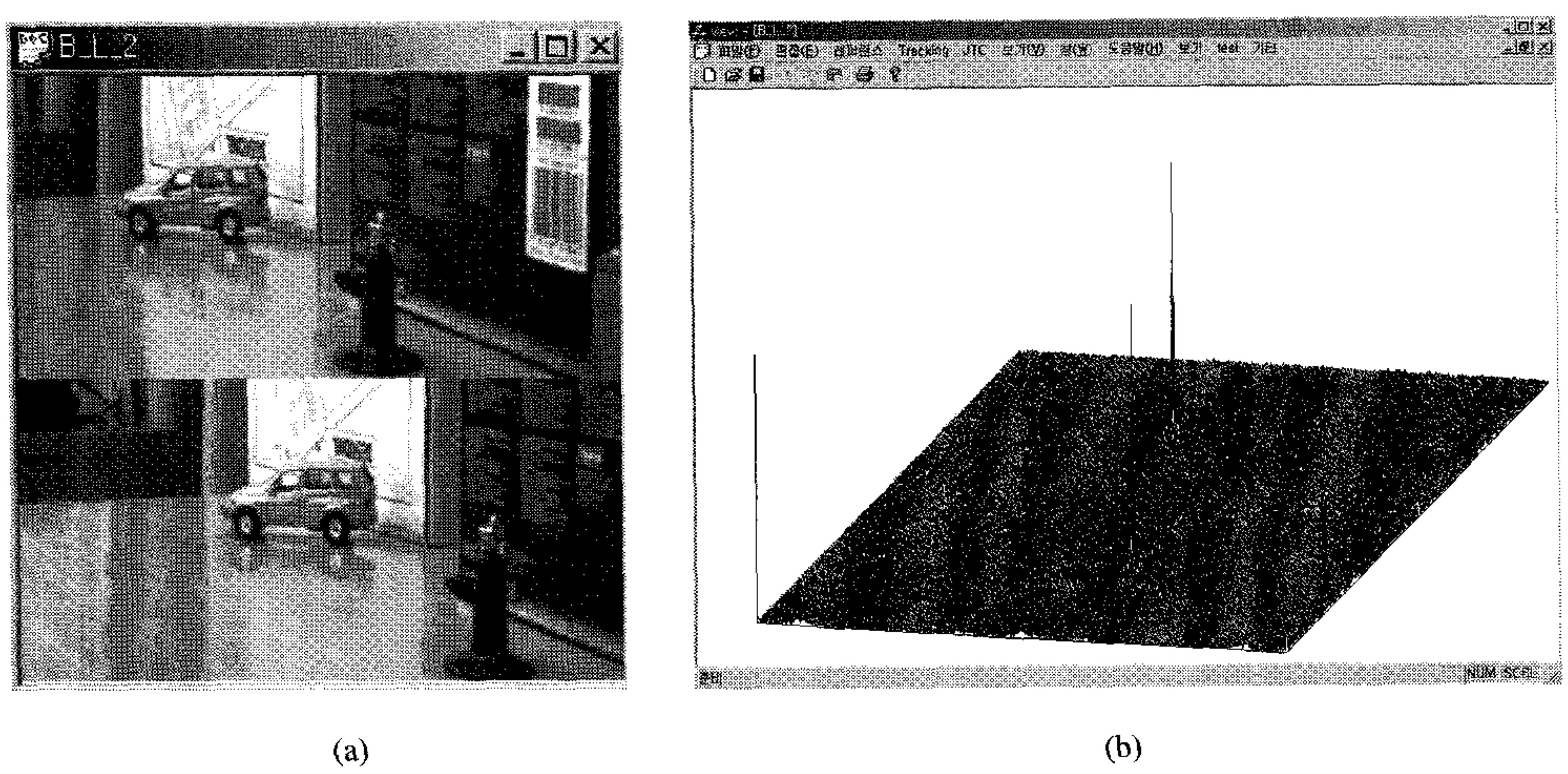

Fig. 5. Simulation results of Optical BPEJTC (a) BPEJTC Input Plane and (b) Correlation Peak.

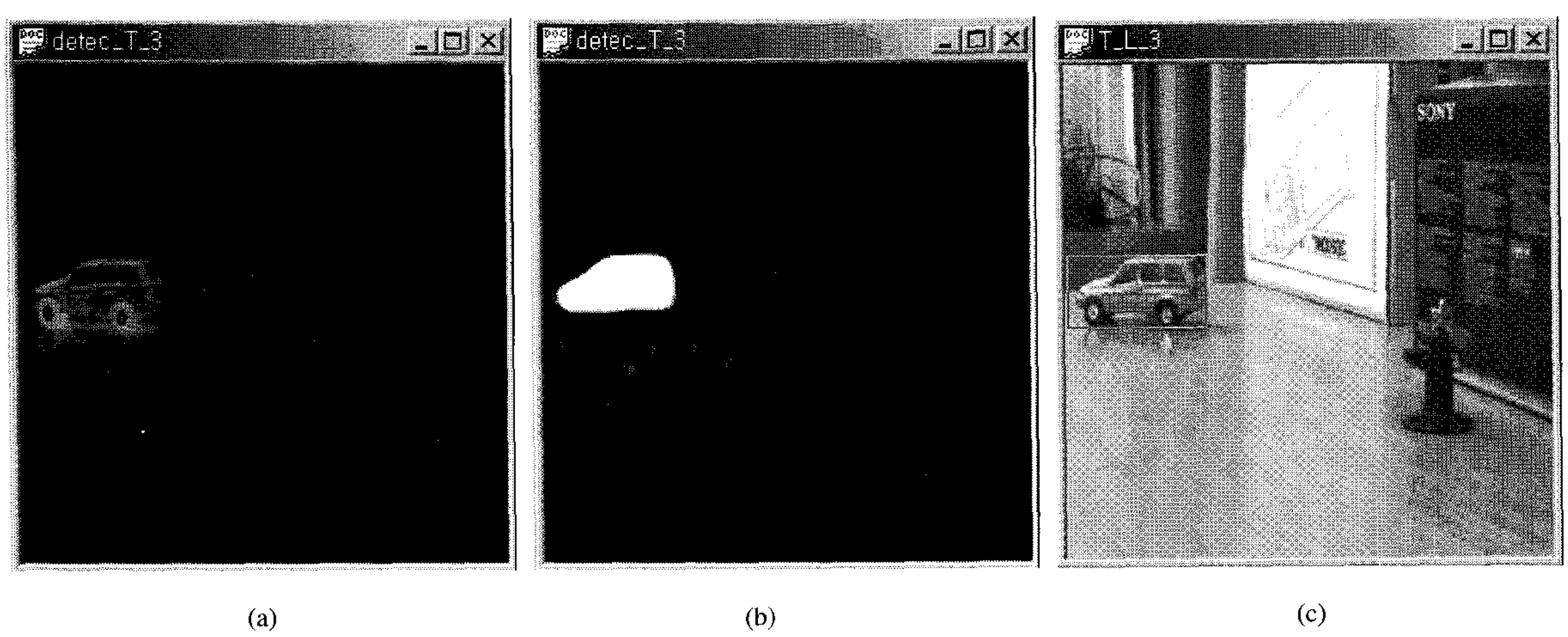

Fig. 6. Target detection and segmentation of left images, (a) Target Extraction, (b) Target Mask, and (c) Target Segmentation.

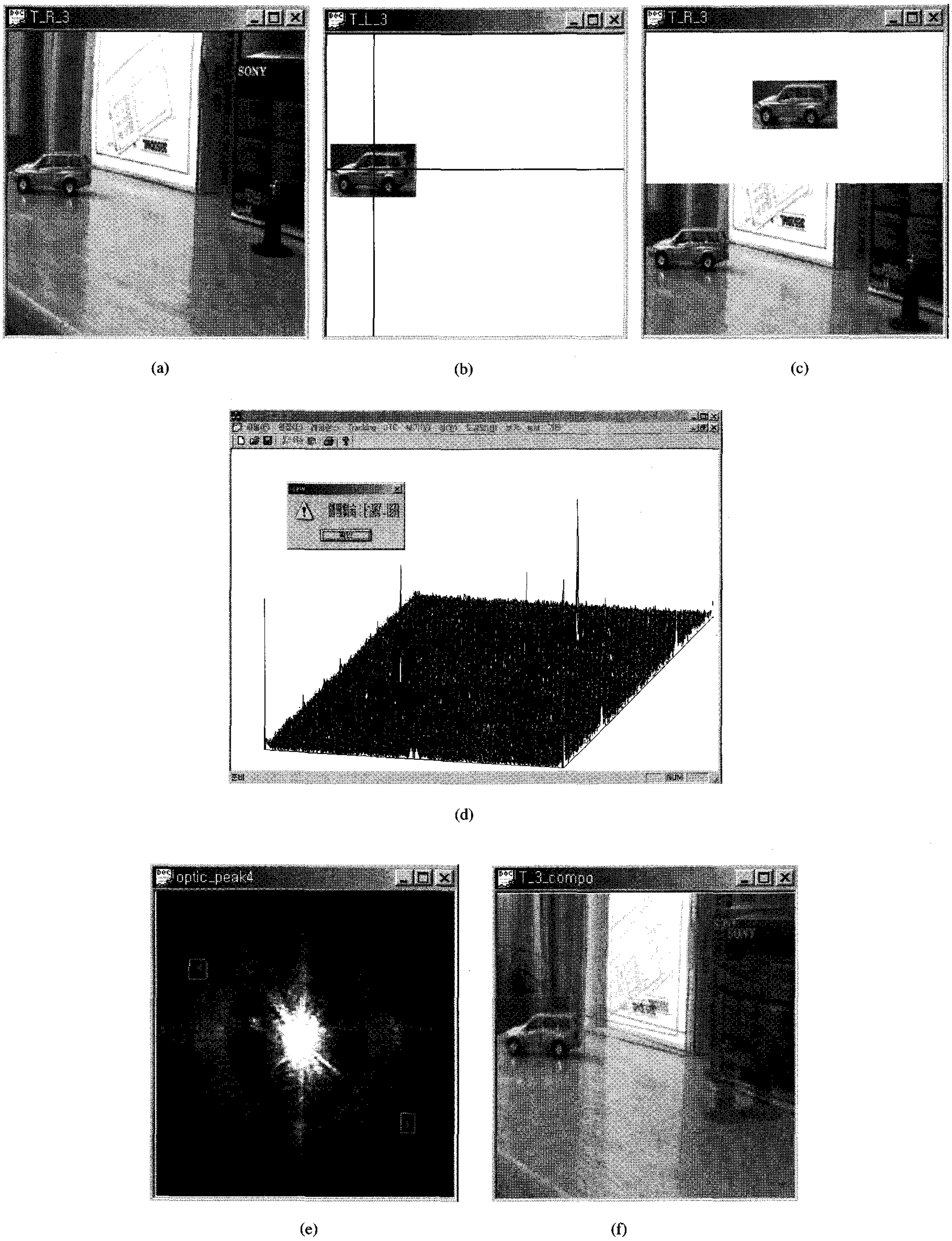

Fig. 7. Simulation results of optical BPEJTC, (a) r(t), (b) Tmask (t), (c) BPEJTC Input Plane, (d) Correlation Peak Point (Simulation Plane), (e) Correlation Peak (Optical Plane), and (f) Composite Image after Convergence Control.

factor of each image is seen to increase as well. And the (-) mark of displacement factor shows the direction that must be moved relatively.

The 3-dimensional description of the position of the correlation peak value is shown in Fig.5. It is possible to remove the background effectively by using the image subtraction filter as the background has been matched based on the results of the correlation of each image.

Fig. 6 shows the results of the target's detection and segmentation, which has been produced by adding the morphology filter after adoption of the detected moving value and has segmented the previous results value by projecting and mapping on the reference image.

Fig. 7 shows the input plane for performing the optical BPEJTC between the left-side image, in which the the target image is detected after segmentation of the target area when the background displacement is bigger than target displacement, and the right side of the image has been inputted in real time.

Table 2 shows the location coordinates (x, y) of the tracking object on the left and the right input images of 4 frames. This coordinate system shows the location coordinates of the tracking object in the (x, y) axis having a central coordinates (0,0) of the 256 × 256 image.

From the above experimental results, it is suggested that effective control of convergence under the condition of background noises is possible through the proposed method, which is based on the difference image information and the optical BPEJTC and which can be implemented in real time.

4. Conclusions

In this paper, a new stereo target tracking algorithm in which the convergence of a moving object can be controlled in the stereo vision system is proposed.

The proposed algorithm, first, extracts the target object by removing the background noises through the difference image information of the sequential left images and then, controls the pan/tilt and convergence angle of the stereo camera by using the coordinates of the target position obtained from the optical BPEJTC, which is executed between the extracted target image and the input image. Also, we propose a novel 3D vision system to detect and segment the moving object adaptively by controlling a pan/tilt system of stereo cameras by using optical BPEJTC.

Based on the some experimental results obtained, the proposed algorithm is found to be capable of extracting the area of the target object from the stereo input image under the circumstance of background noises by using the target mask and then tracking the stereo object through controlling the convergence angle and pan/tilt of stereo cameras by using the location values of the tracking object obtained from the optical BPEJTC.

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