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Real-world Applications on the Reconfigurable-VLSI-based Double-lens Tracking-camera

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Abstract

We propose a double-lens tracking-camera system composed of two lens-modules. One module is to take a wide view while the other is to track and magnify the target with its pan-tilt mechanism, which mimics the eye's function of tracking and watching an object without losing wide whole view. We have developed a prototype of the camera and applied it two real-world applications, i.e., "fish-tracking" and "illegal-disposal-surveillance", and had excellent results fundamentally in the applications.

1. Introduction

Our goal is to develop a camera that has the eye's function of tracking and watching an object without losing wide whole view. We have developed a prototype of the camera and reported its fundamental performance already[1][2]. In the first prototype, we have introduced "Real Time Template Updating (RTTU)" algorithm in which the target area in the previous image frame is used for the template for the target in the current image frame, and then the target area in the current image frame is used for the template in the next image frame. The algorithm was implemented onto a reconfigurable VLSI, or FPGA (Field Programmable Gate Array), and the prototype worked well basically under the algorithm. Miss-tracking, however, also happened occasionally because slight positioning shift of the target to the center of the template was accumulated and the target was shifted out of the center gradually.

In order to overcome this difficulty, we have proposed "Center of Gravity Adjustment (CGA)" algorithm in which the center of the gravity of the template is moved to the center of the template. By combining the RTTU with the CGA, we could achieve much more precise tracking successfully in the second prototype.

We have applied the prototype to two real-world applications, i.e., "fish-tracking" and "illegal-disposal-surveillance", and had excellent results fundamentally in the applications. In this paper, we explain the newly proposed algorithm of RTTU with CGA and discuss the experimental results of the applications showing its images.

2. System Overview

Figures 1 and 2 show a photograph of the double-lens tracking-camera prototype and the FPGA-board, respectively. An FPGA, which is a kind of programmable VLSI, is mounted on the FPGA-board (a black-colored square part at the center of the board is the FPGA). A wide view is captured through the wide-view lens module (the small-lens module in the figure) in the beginning, and it is sent into an FPGA a target-tracking-and-detection algorithm is implemented onto. In the FPGA, the target position is detected immediately and it is fed back to the other lens-module for the telescope view with the pan-tilt mechanism. We also newly developed a magnet-based pan-tilt drive in place of the traditional motor-based drive, which enables the lens-module to move faster than the traditional one by tree times or more (see details in [1][2]).

3. Target-detection and Tracking Algorithm

A target can be detected based on the template-matching manner fundamentally. In the simplest approach, pre-sampled target-image-templates are scanned through the whole image and the object matched to some templates is detected in it. In the ordinary approach, however, it is getting difficult to track the object correctly as its moving-speed increases. In our system, the target-image-template is updated during the tracking, which is called "Real Time Template Updating (RTTU)" algorithm, contrastively to the fixed set of the pre-sampled target-image-templates. The target image that has been tracked in one previous frame t_{n-1} is used as the template for the present frame of t_n. According to this updating procedure, the template is updated in real-time, or on-line manner. The target image in the present frame t_n is almost the same as in the previous one in the frame t_{n-1}, so that the template-image can correctly matches the target even under its high-speed motion because of the very short interval between frames. Under the RTTU algorithm, the target thus can be rocked in the tracking fundamentally.

The real-time updating mentioned above works well principally if the updating interval is much shorter than the target motion. The video-frame-rate of 33ms, however, is not so short to the target that moves fast close to the camera, and it sometimes happens that the center of the target gradually moves from that of the template and the tracking fails finally.

This miss-tracking mechanism is analyzed in Fig. 3. The figure shows the template and its correspondence to the frame at every frame step of t_i, which is usually 33ms in video frame. The template consists of 8 x 8 segments, or pixels and that is a part of the frame of 10 x 13. In the prototype, a frame of 100 x 72 segments, which is sampled from the original digital image of 768 x 494 pixels, is used. In this explanation, the frame size is reduced to 10 x 13 for the sake of convenience. In the figure, an "L"-shape like target simply moves to the right side without changing its shape. The target is at the center in the template at t_0, and it is exactly matched with the target in the frame at t_0. Then the template at t_1 is cut out from the frame at t_0 and it is the same as at t_0. The target in the frame at t_1 is a little different from that at t_0 because the target moves a little and the quantumization error occurs in the image even though the target itself does not change in its shape. Thus, some difference in shape happens between the targets in the template and the frame. The target image in the frame is recovered at t_5, and the target image in the template at t_6 is recovered according to it. The target-image-position, however, is shifted by 1 segment to the right as shown in figure. This target-image-shift in the template goes as the time increases. At t_{10}, the target-image-position is sifted by 2 segments to the right compared with that at t_0. Finally, as shown in the figure, the target image disappears at t_{30}. The RTTU algorithm thus does not work well by itself because of the quantumization error practically.

In order to overcome this difficulty, we propose the Center of Gravity Adjustment (CGA) algorithm. In the CGA, the center of the gravity of the template P_{cg} is calculated as follows:

$$P_{cg}\left(x_{cg}, y_{cg}\right) = \left(\frac{\sum p_k x_k}{\sum p_k}, \frac{\sum p_k y_k}{\sum p_k} \right),$$

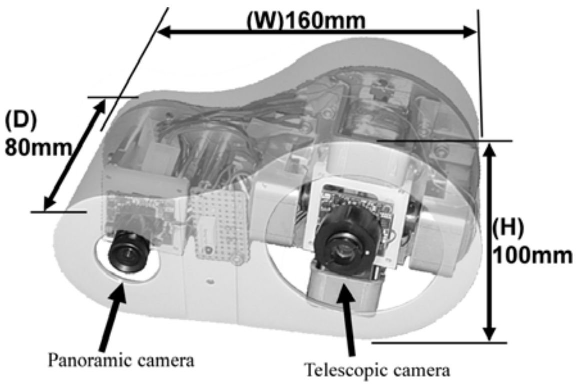

Fig. 1 Double-lens tracking-camera.

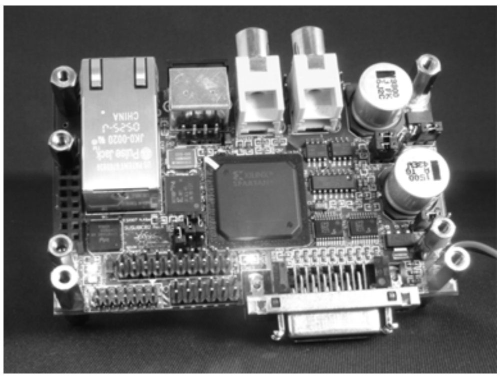

Fig. 2 FPGA board.

where P_k is the value (brightness) of the k-th pixel in the template and x_k and y_k are the x and y coordinates of the pixel, respectively. And P_{cg} is adjusted to the center of the template at every frame rate.

4. Applications

4.1 Fish-Tracking

We applied the system to the fish-tracking in which a target fish was detected among multiple fish in an aquarium under the wide-lens view and the target was tracked being magnified through the telescope-lens module. We also developed the network interface to connect the camera with the Internet to broadcast the live images widely.

Figure 4 shows a magnified image of the target fish tracked with the pan-tilt telescope lens module, while Fig. 5 shows the wide-lens view of the entire aquarium. The template that is cut out from the frame in Fig. 5 is also superimposed at the upper left corner.

The target fish in the entire aquarium image is magnified by 3-time, so that its face and fins can be clearly observed. In the application, the target fish could be tracked successfully even under the multiple fish, algae, stones with water circulation and pumped air. Observers could watch the target fish clearly seeing the entire aquarium.

4.2 Illegal-Disposal-Surveillance

Illegal-disposal is one of serious social problems, especially in Japan. Some imprudent person throws away bulky refuse, or garbage to some field illegally. Conventional surveillance-cameras are set up in some field already. The cameras, however, capture entire wide views of fields only. Thus, it is sometimes difficult to identify the criminals.

We are planning to apply the double-lens tracking-camera to the illegal-disposal-surveillance to solve the problem by its feature of tracking and magnifying the target. We have carried out some surveillance tests using the prototype. Figure 6 shows a wide-lens view of the entire filed a person having garbage in his hand is captured in (this is not a real illegal-disposal but is just an act). The template that is cut out from the frame in Fig. 6 is also superimposed at the upper left corner as in Fig. 6. Figure 7 shows a magnified image of the person being tracked with the pan-tilt telescope lens module. In this application, we used a 6-power lens corresponding to the wide area of the field. The person can be clearly shown and identified easily.

In the illegal-disposal-surveillance, however, some over swings or trembles still remain in the pan-tilt camera movement because the wide-view area in the illegal-disposal-surveillance is much wider than the fish-tracking. This difficulty is expected to be improved with high-precision digital feed-back control that is planed to be added to the current feed-back circuits.

5.Conclusions

The Real Time Template Updating (RTTU) algorithm with Center of Gravity Adjustment (CGA) was proposed in order to achieve highly precise tracking, and it was implemented onto the FPGA in the double-lens tracking camera.

The camera was applied to the real world applications of the fish-tracking and the illegal-disposal-surveillance. In the fish-tracking, the target fish in an aquarium could be tracked successfully even under the natural situation of the aquarium. In the illegal-disposal-surveillance,

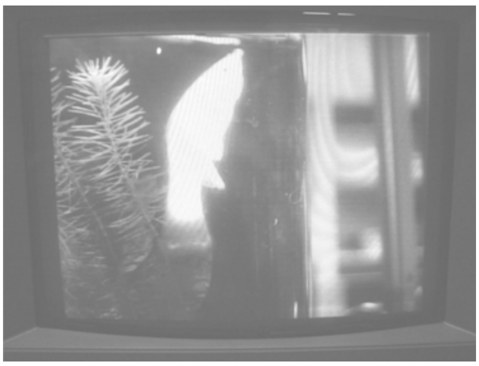

Fig. 4 Magnified image of the target fish.

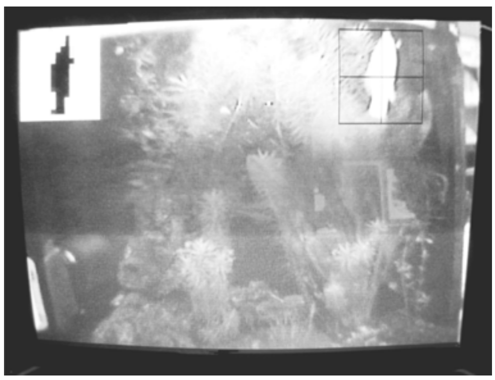

Fig. 5 Wide-lens view of the entire aquarium.

the target (a parson) could be tracked also, but some over swings or trembles still remained in the pan-tilt camera movement, which was expected to be improved by the digital feed-back control.

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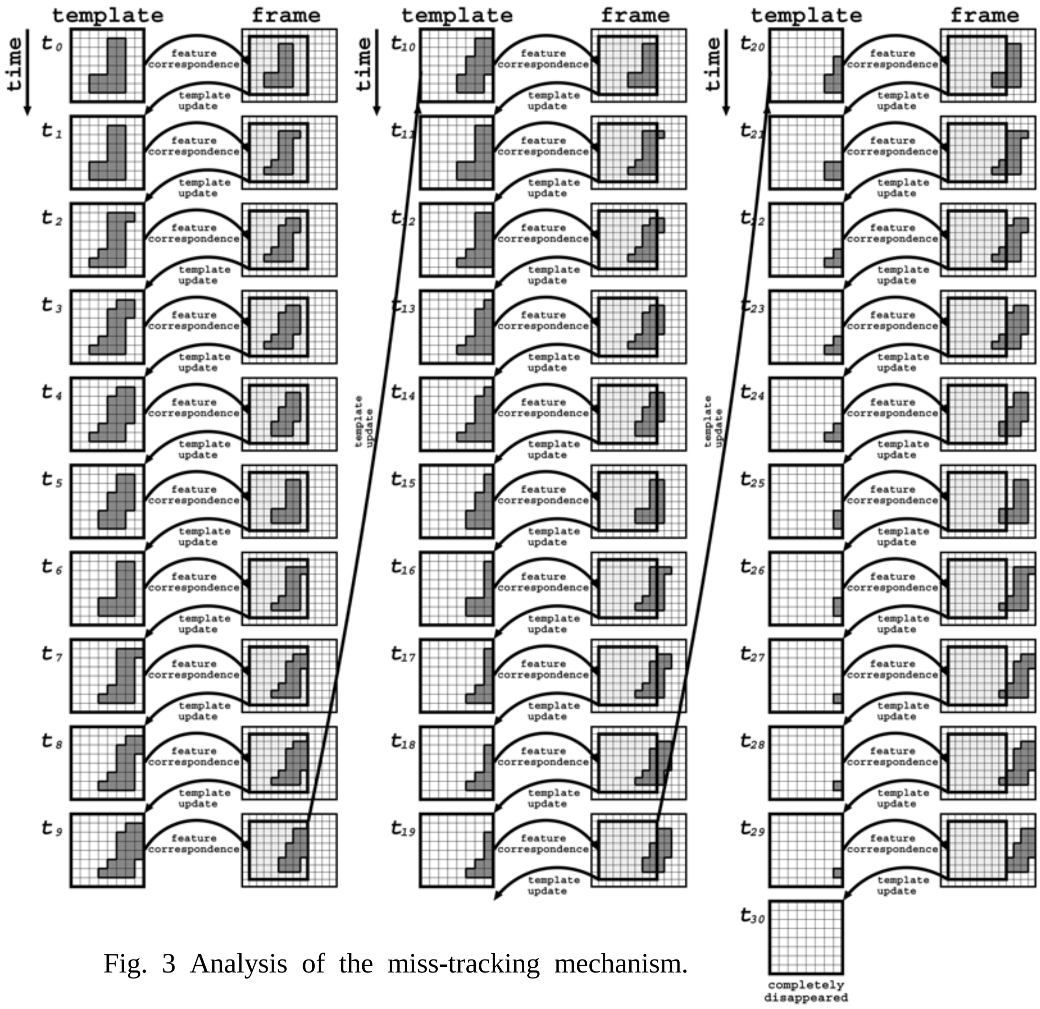

Fig. 3 Analysis of the miss-tracking mechanism.

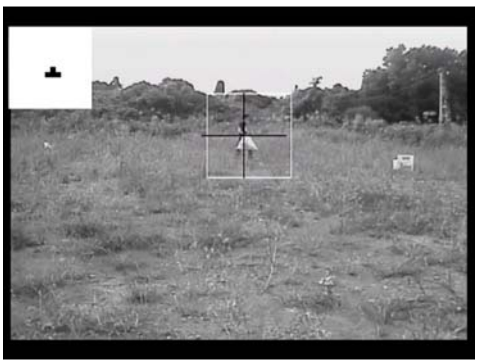

Fig. 6 Wide-lens view of the entire field.

Fig. 7 Magnified image of the person.

