A Reconfigurable-VLSI-based Double-lens Tracking-camera

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Abstract

Watching and tracking an object as seeing a wide whole view is one of advantages in the eye-system. We propose and develop a tracking camera system that mimics the eyes using double-lens modules. In the system, a wide whole view is captured through the wide-lens module while the target in it is tracked and magnified through the telescope-lens module. Electronic circuits for the tracking control are implemented onto the reconfigurable VLSI, or FPGA in order to embed the parallelism in the tracking algorithm into the hardware. An FPGA-based prototype developed successfully performs high speed tracking along with the video-rate.

1. Introduction

We human beings can watch and track an object without losing wide whole view. Thanks to this simple concurrent function, but with complex mechanism, of the eye we can recognize the target correctly under huge amount of information rushes into the brain via the eyes. Our goal in this paper is to propose and develop a novel tracking-camera composed of double-lens modules for wide and telescope views concurrently, which is the same function as the human eye has.

Initially, we designed a camera with a single lens-module system that resembled the eye in appearance. It has been, however, turned out that a fine-resolution sensor-device with high-speed random access capability is indispensable for the single lens-module system and its cost is much more expensive than for the consumer product.

On the basis of the initial examination mentioned above, in this paper, we propose a camera system consists of two lens-modules: one module is to capture wide views while the other one is to track and magnify the target with its pan-tilt mechanism. This camera system has been designed and developed based on the Bio-inspired camera [1] and the PNN (Probabilistic Neural Network) pattern recognition system [2] that was developed by us using FPGAs (Field Programmable Gate Array). On these days, the FPGA, in which we can reconfigure its logic circuits anytime in contrast to the VLSI processor or DSP, is getting well known and is widely used for rapid-prototyping-design in hardware developments. Novel architectures for the new tracking camera have been efficiently and easily implemented onto the previous systems and we could achieve a high-speed tracking process to keep up with the video-frame rate of 33ms through the reconfigurabilty of the FPGA.

2. Overview of the Tracking Camera System

Figures 1 and 2 show a photograph and a design for the double-lens tracking-camera prototype, respectively (an electrical-circuit board mounting an FPGA to control the camera is not included in it). Whole views are captured through the wide-view lens module (the small-lens module in the figure) in the beginning, and the captured images are processed in an FPGA. 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 (the large-lens module in the figure). The double-lens tracking camera does not closely

Fig. 1 Photograph of the Double-lens tracking-camera.

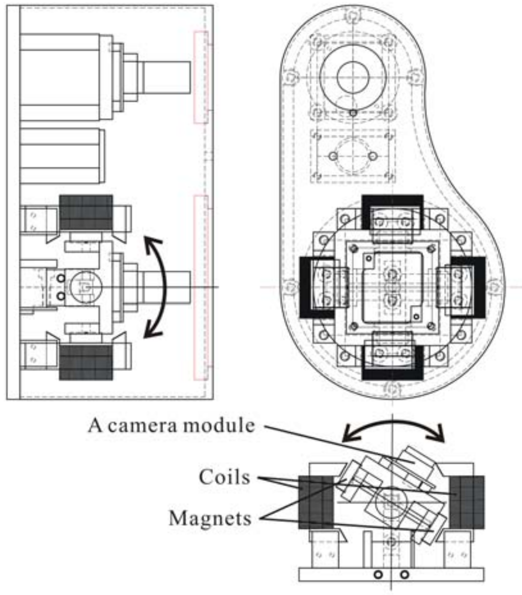

Fig. 2 Design for the Double-lens tracking-camera.

resemble the eye in appearance, but it gives us the same function as the eye has inexpensively.

Furthermore, 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. The motor-based drive consists not only of the magnetic parts but also of the other mechanical parts that impede the camera from high-speed rotation and small size, while the troublesome mechanical parts are removed in the magnet-based pan-tilt drive.

With the newly developed magnet-based drive (see Fig. 2), the lens-module is directly driven to move in the pan-tilt directions. The lens-module has four magnets in the right-angled direction each other. An electromagnet is placed opposite to the four magnets and driving forces to move the lens module are generated and controlled by the amplitude and the directions of the current applied to the electromagnet. We could achieve high-speed pan-tilt movement of about 3-time faster and reduce its size to less than 1/2 of the conventional pan-tilt camera by the direct-drive mechanism.

Figure 3 shows a photograph of the electrical-circuit board to control the camera at the tracking-speed-rate of 33ms/frame. A novel tracking-algorithm, in which the image-template for the tracking process is updated according to the captured target-image in every frame rate of 33 ms interval (details are described later), is implemented into the FPGA. The camera shown in Fig. 1 controlled by the board demonstrates high-speed performance enough for the fish-tracking application in which the target fish is detected among a group of fish and is tracked with its magnified picture in an aquarium (details are described later).

The tracking algorithm described in the next section can be also implemented onto the general-purpose processors or DSPs. The software-based processing, however, does not fit to the sequence of the tracking processes because the intrinsic parallelism in the processes cannot be embedded into the programs. On the contrary, we can implement the parallelism as it is onto the FPGA, so that the tracking-procedure can be executed at the video-frame rate or more. Furthermore, by using FPGA, some parameters in the algorithm can be embedded into the logic circuits directly and they can be changed to meet each application. This hardware tuning improves the system performance well to meet desired conditions depending on each application.

3.Tracking Architecture for the Double-lens Camera

Figure 4 shows the block diagram according with the signal flow form the wide-lens camera module to the telescope lens camera module.

A whole view including the target is captured with the wide-lens module. During the A/D

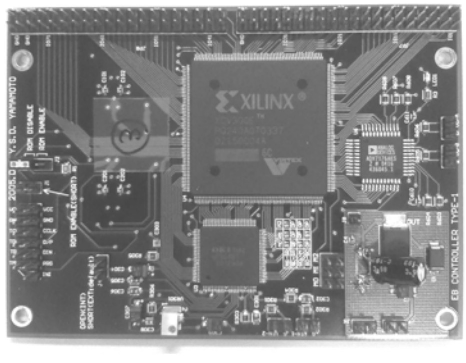

Fig. 3 Photograph of the FPGA-board.

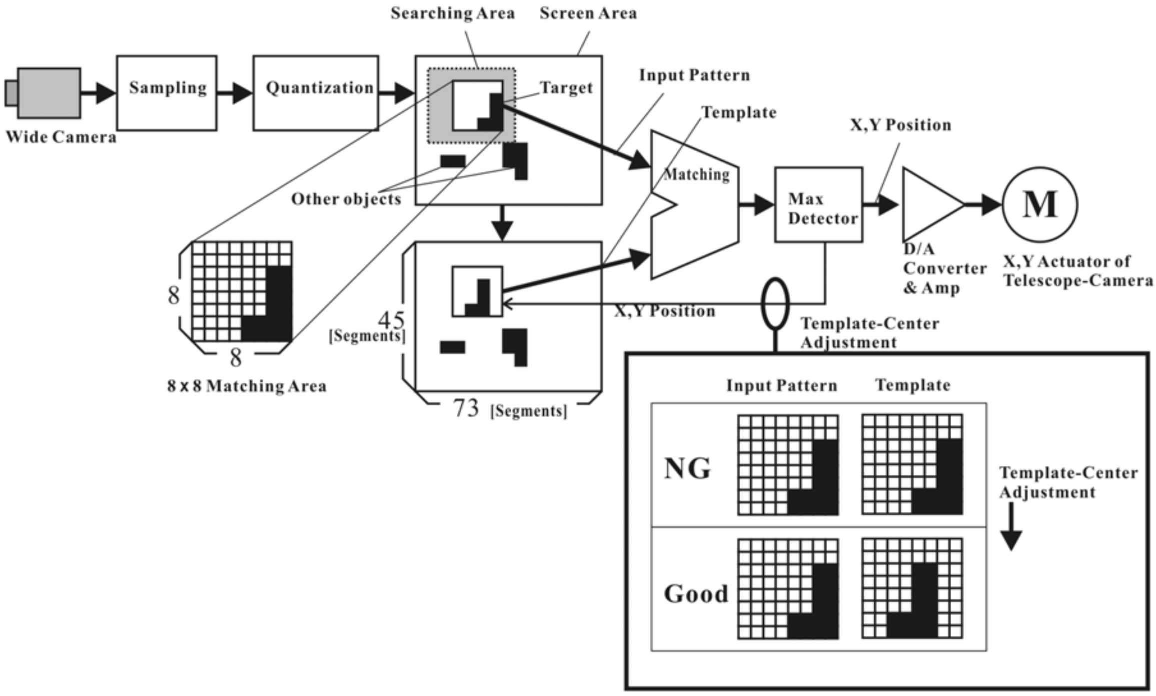

Fig. 4 Block-diagram of the tracking-process.

conversion process, the image is preprocessed before the target detection. The entire image is sampled digitally and its image size is reduced to 45 x 73 pixels. Each pixel is also digitalized or, quantized to 8-bit. The size reduction-rate and the quantization-rate are not fixed to 45 x 73 and 8-bit (we use binary quantization in the application in this paper). Those values can be changed and implemented, that is, reconfigured easily onto the FPGA directly.

In the ordinary algorithms for the target detection, the pre-sampled target-image-templates are scanned through the whole image and the object matched to the target is searched 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, contrastively to the fixed set of the pre-sampled target-image-templates. The target image that was 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 real-time updating procedure, the target thus can be precisely rocked in the tracking.

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.

In order to overcome this problem, we propose the following center-feedback algorithm and implement it in the system:

1) The weighed center of the template is calculated.
2) The difference, or distance between the weighted center and template center is calculated.
3) The template the center of which is adjusted is re-captured according to the difference calculated in 2).

The position of the target is searched in every frame using the template under the center-feedback algorithm. The most matched area to the template is detected and its position is output through the comparator and the max-detector. The detected position is converted to analog signal finally and is input to the pan-tilt drive of the telescope camera.

The real-time updating in the template has been reported in the other system already [3]. In [3], however, real-time updating was applied to the convolution images. We have overcome the problem of the real-time updating applied to the original images.

Fig. 5 A screen-shot of the fish-tracking.

4. Application to the Fish Tracking

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

Figure 5 shows a screen-shot of the broadcasted image via the Internet. The upper-right picture shows the magnified image of the target fish tracked with the pan-tilt telescope lens module while the upper-left picture shows the wide-lens view of the entire aquarium. The target fish in the entire aquarium image is magnified by 3-time, so that its face and fins can be clearly observed. The lower-left and lower-right images are taken with another camera for the demonstration purpose. The lower-left picture shows the entire demonstration system in which the camera is set in front of the aquarium (the shield of the camera is removed). The lower-right picture shows the telescope-lens module tracking the target.

In the application, the target fish could be tracked successfully even under the multiple fish circumstances. And observers could watch the target fish clearly seeing the entire aquarium. We are now planning to apply this double-lens tracking-camera to the real surveillance applications.

5.Conclusions

A tracking-camera mimicking the eye was proposed and developed. The camera consists of double-lens modules: one for the wide-view and the other for the telescope view of the tracked target. The center-feedback algorithm was proposed and it was implemented onto a FPGA to track objects at high-speed motion. A magnet-based pan-tilt drive was also developed for high-speed tracking. A prototype of the camera was developed and it showed desired performances in a fish-tracking application.

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References

[1] N. Aibe, et al., "Performance Evaluation System for Probabilistic Neural Network Hardware," Proc. International Symposium on Artificial Life and Robotics (AROB 8th '03), pp.471-474, January 2003.

[2] K. Hayashi, et al.,"A Bio-inspired Tracking-camera System", International Symposium on Artificial Life and Robotics (AROB 11th '06), pp.755-758, Japan, 2006.

[3] S. C. Wong, M. Jasiunas, and D. Kearney, "TOWARD A RECONFIGURABLE TRACKING SYSTEM," Proc. 2005 International Conference on Field Programmable Logic and Applications (FPL), pp. 456-462, August 2005.