High-Speed Visual Tracking of the Nearest Point of an Object Using 1,000-fps Adaptive Pattern Projection*

Tomoyuki Inoue, Shingo Kagami, Joji Takei, Koichi Hashimoto
Tohoku University, 6-6-01 Aramaki Aza Aoba, Aoba-ku, Sendai 980-8579, Japan
`{inoue,swk}@ic.is.tohoku.ac.jp`

Kenkichi Yamamoto, Idaku Ishii
Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima 739-8527, Japan

Abstract

A 1,000-fps camera-projector system in which projected patterns are adaptively controlled according to image processing results is described. Adaptive structured light projection enables fast and efficient 3-D information acquisition. The prototype system is applied to the tracking of the nearest point of an object, and experimental results show that the system successfully tracked an apex of a fast-moving target object.

1. Introduction

Active stereo methods using structured light projection are widely used for vision-based 3-D shape recognition. Most of existing systems, however, are not fast enough for fast dynamic scenes to be measured, and many recent studies focused on achieving high-speed measurement. For example, we recently achieved 3,000-fps 3-D measurement using a 6,000-fps camera-projector system [1].

On the other hand, for some applications such as object tracking, obtaining a 3-D range map of the whole image is not necessary, and smart scanning of the limited area of interest is rather preferred. As such an example, Cassinelli et al. developed a system for tracking of objects such as fingertips or small balls using an active point laser and a single-pixel photo detector [2].

In this paper, we describe a real-time tracking system that utilizes the 3-D shape of objects. The system consists of a 1,000-fps camera-projector system in which projected patterns are controlled in real time based on the camera information. As an example of shape information, we demonstrate tracking of the nearest point of an object.

2. System Configuration

The developed system consists of a high-speed projector and a high-speed vision system, both of which are controlled by a PC with dual Intel Xeon 2.8 GHz CPUs as shown in Figures 1 and 2.

A $1,024 \times 1,024$ pixels image captured by a Photron FASTCAM-1024PCI camera head is transferred at 1,000 fps to an FPGA image processing board developed by the authors at Hiroshima University [3]. According to the processing results, the PC controls the projector in real time.

The high-speed projector is a disassembled InFocus LP600 combined with a Texas Instruments Digital Micromirror Device [4] (DMD 0.7XGA 12DDR), its starter-kit controller board DMD Discovery 1100, and a ViALUX

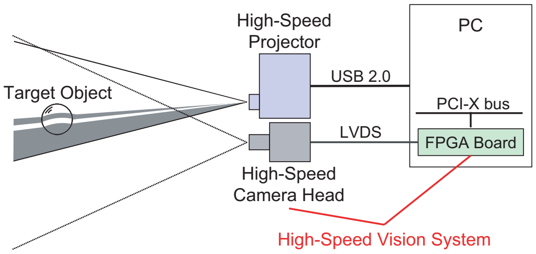

Figure 1. System configuration

(a) (b)

Figure 2. (a) High-speed projector and high-speed camera head, and (b) FPGA board

---

*Part of this study is a joint work with Photron Limited supported by the Grant of the New Energy and Industrial Technology Development Organization (NEDO), Japan.

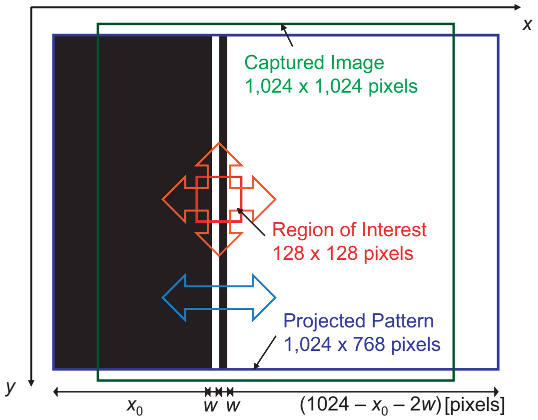

Figure 3. A projected pattern and the region of interest (ROI)

ALP-1 pattern storage board. $1,024 \times 768$ pixels binary images can be projected at around 10,000 fps at maximum.

In typical usage of the pattern storage board ALP-1, a fixed pattern sequence (e.g. Gray code patterns, or PWM-based fringe patterns) is stored in the storage memory and the sequence is projected repeatedly. On the other hand, our system requires adaptive pattern projection instead of fixed sequence projection. We implemented this by storing many sequences each of which contains only a single pattern and selecting an arbitrary sequence (that is, a pattern) to be projected in real time through the USB link.

3. Nearest-Point Tracking

As a demonstration, we implemented a “nearest point” tracking algorithm. Figure 3 illustrates a projected pattern and the image region of interest (ROI). The pattern consists of four vertical stripes, namely from left to right, a x_0-pixels width black stripe, w-pixels white, w-pixels black, and $(1,024 - x_0 - 2w)$-pixels white. The position of the central two stripes, x_0, is dynamically controlled.

The FPGA board extracts the 128×128 pixels ROI and transfers it into the main memory of the PC. The PC then detects three vertical edges between the four stripes. For the nearest-point tracking, we use local orientation of the object surface, which are obtained from the depths at the three edges measured by triangulation. For simplicity we used the disparities instead of computing the precise depths.

For the x-direction controls of the projected stripes and the ROI position, the 128×32 pixels region at the center of ROI is used. If the left (right) edge is the nearest of the three on average in this region, the projected stripes and the ROI are moved to left (right). If the center edge is the nearest, they are not moved in x direction. For the y-direction control of the ROI, all of the extracted 128×128 pixels are used and the y position of the ROI is moved so that the nearest point comes at the center of the ROI.

Figure 4 shows an experimental result. The stripes width w was set to 8 [pixels]. Both of the vision system and the projector operated at 1,000 fps. An apex of a randomly moved white rectangular solid was successfully tracked.

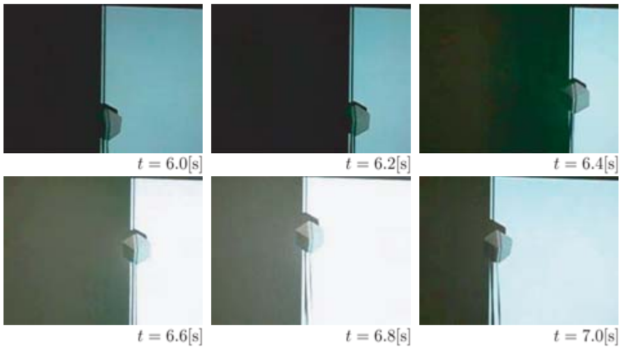

Figure 4. Experimental result

4. Conclusion

A 1,000-fps camera-projector system in which projected patterns are adaptively controlled according to image processing results has been presented with application to object tracking based on target shape information.

This work is just preliminary. The pattern generation capability of our prototype system is limited by the storage memory size. In the present implementation, 2,730 patterns at maximum can be stored. The flexibility of projectable patterns will be improved when we implement a real-time pattern generation hardware in future work, and it will enable more sophisticated applications through, for example, multiple object tracking without loss of speed or use of more complicated shape information. Implementing precise synchronization between the camera and the projector will improve the robustness against background illumination of scene colors through differential detection using complimentary pattern projection.

References

[1] J. Takei, S. Kagami and K. Hashimoto. 3,000-fps 3-D Shape Measurement Using a High-Speed Camera-Projector System. Submitted for publication in *2007 IEEE/RSJ Intl. Conf. Intelligent Robots and Systems (IROS2007)*. 1

[2] A. Cassinelli, S. Perrin and M. Ishikawa. Smart Laser-Scanner for 3D Human-Machine Interface. *ACM SIGCHI Conf. Human Factors in Computing Systems (CHI2005)*, 1138–1139, 2005. 1

[3] K. Fujiwara, K. Yamamoto and I. Ishii. Development of All-Pixels Processing Type High-speed Mega Pixel Vision. *12th Symp. Sensing via Image Information (SSII06)*, D-4:88–92, 2006. (in Japanese) 1

[4] D. Dudley, W. Duncan, J. Slaughter. Emerging Digital Micromirror Device (DMD) Applications. *Proc. SPIE*, 4985:14–25, 2003. 1